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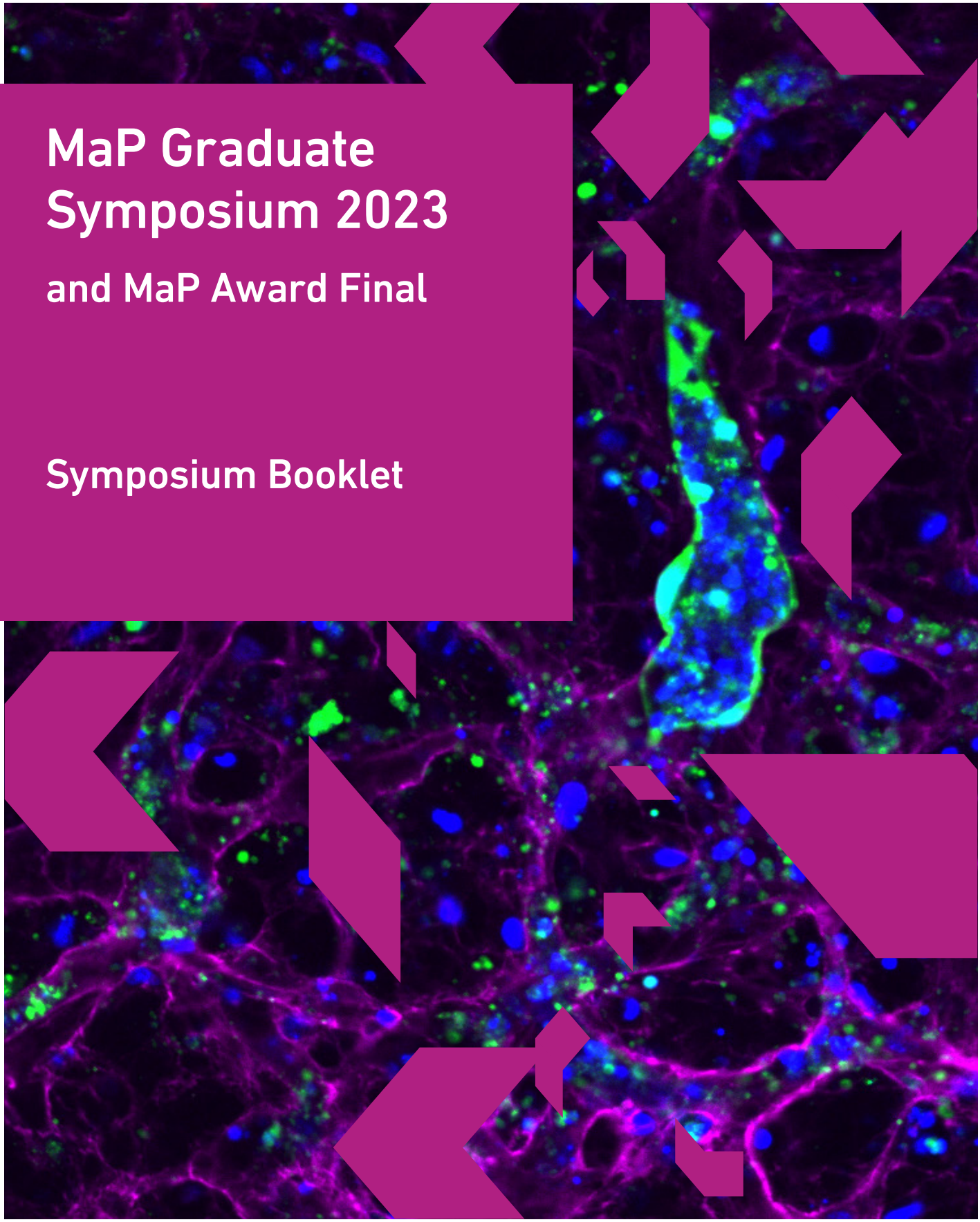

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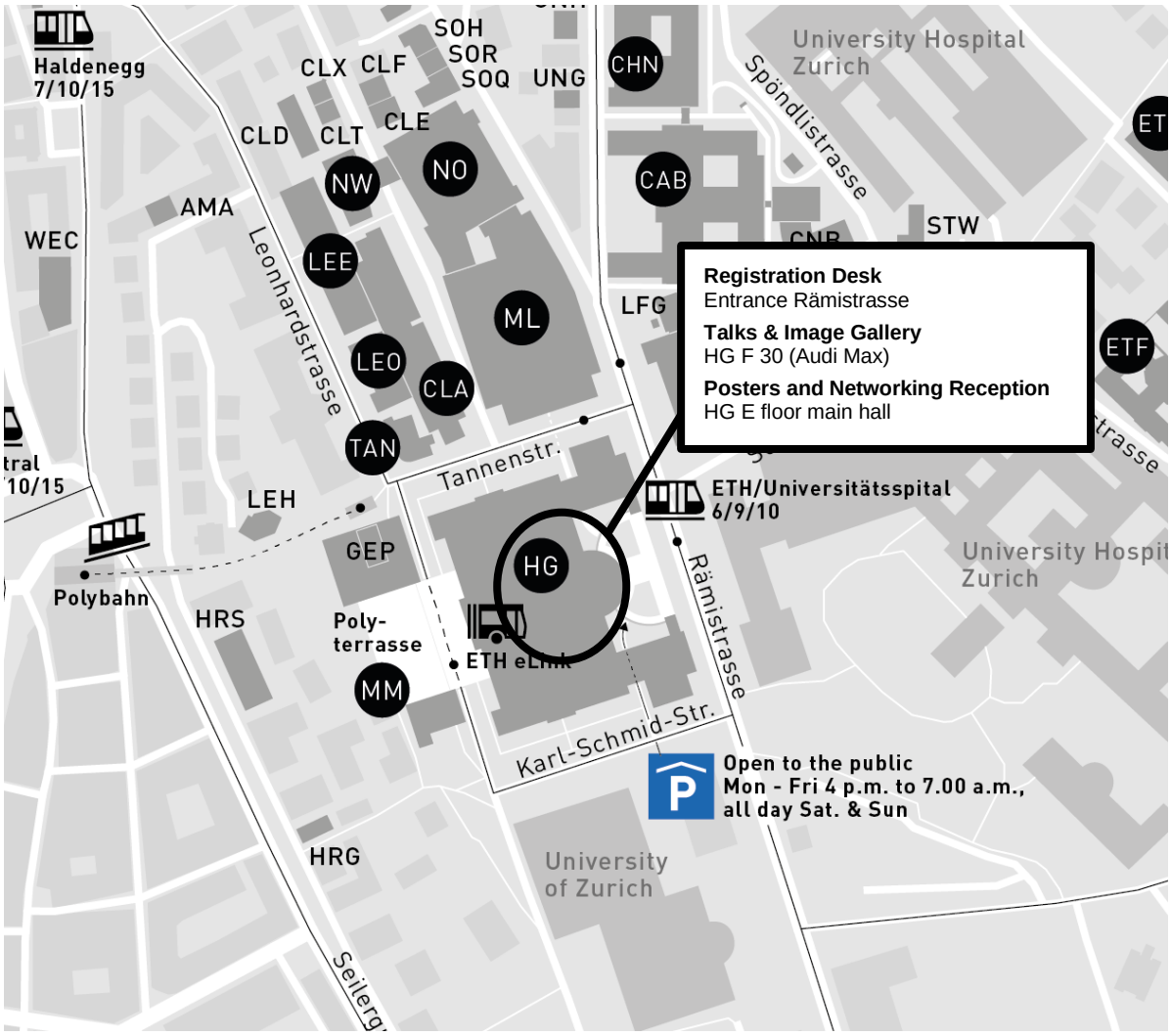

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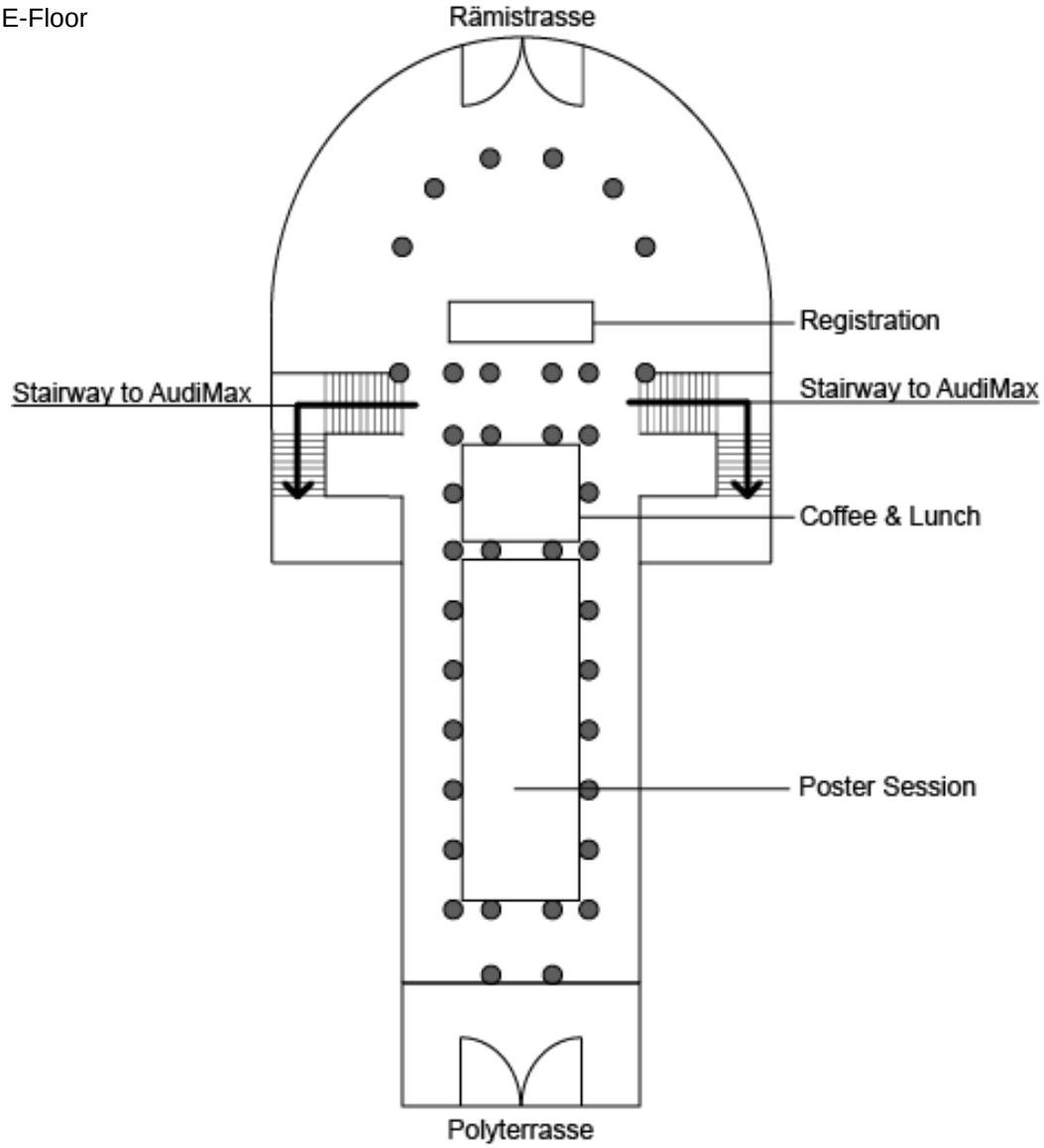
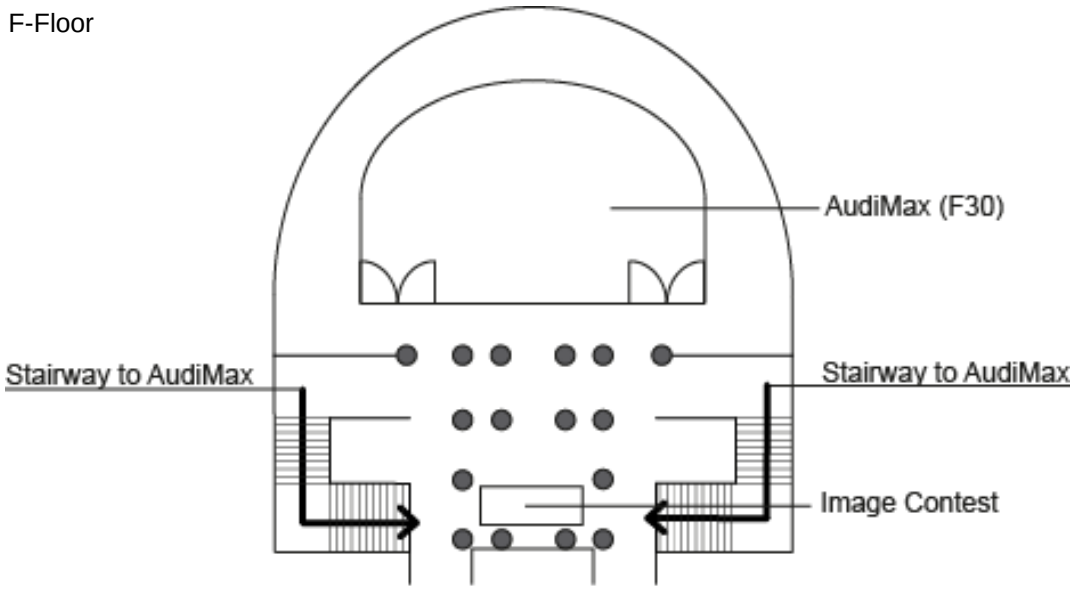


HG F-Floor



Programme

08.00	Registration
08.45	Opening Remarks
09.00	**Ioanna Mitropoulou**, *Digital Building Technologies, D-ARCH* Non-Planar Layered Morphologies
	Lorenza Garau Paganella, *Experimental Continuum Mechanics / Macromolecular Engineering, D-MAVT* 3D Hydrogel Platforms to Study Skin Cell Response to Hydrostatic Pressure
	Mahmoud Medany, *Acoustic Robotics for Life Science and Healthcare, D-MAVT* Precision Guided Non-Invasive Treatment of Aneurysms Using Acoustic Robotics
	Luca Marin, *Materials Theory, D-MATL* Density Functional Theory Description of Xenon for Light Dark Matter Direct Detection
	Ipek Efe, *Multifunctional Ferroic Materials, D-MATL* Nanoscale Design of Layered Ferroelectrics for Future Smart Electronics
10.00	Coffee Break & Poster Session
11.00	**Kostas Parkatzidis**, *Polymeric Materials, D-MATL* Environmentally Friendly Light-driven Chemical Recycling of Polymers Back to Virgin Monomers
	Florence Müller, *Soft Materials, D-MATL* A Modular Silica Core-Shell Synthesis Particle Platform: Rough, Sticky and yet Reversible Colloidal Gels
	Monika Zimmermann, *Nanoparticle Systems Engineering, D-MAVT* Radiotherapy Enhancement by Ti3C2Tx MXenes
	Julian Schmid, *Multiphase Thermofluidics and Surface Nanoengineering, D-MAVT* Microscale Investigation on Interfacial Removal of Microfoulants from Soft Materials
	Ali Jafarabadi, *Structural Mechanics and Monitoring, D-BAUG* 4D Printing of Recoverable Buckling-Induced Architected Iron-Based Shape Memory Alloys
12.00	Lunch & Poster Session

(continued)

MaP Award 2023

13.30 **Dr. Lukas Gerken**, *Nanoparticle Systems Engineering, D-MAVT*

Rational Design of Nanoparticle Radioenhancers for Precision Radiotherapy

Dr. Mattia Halter, *Computational Nanoelectronics, D-ITET*

Ferroelectric Memristors for Neuromorphic Applications: Design, Fabrication and Integration

Dr. Amogh Kinikar, *Magnetism and Interface Physics, Empa & D-MATL*

New Polymerization and Post-Synthesis Strategies in On-Surface Synthesis

Dr. Riccardo Rizzo, *Tissue Engineering and Biofabrication, D-HEST*

Development and Application of Photosensitive Bioresins for 3D Biofabrication Strategies. From Volumetric Printing to Two-Photon Stereolithography

15.00 Coffee Break

15.30 **Andrea Rich**, *Metal Physics and Technology, D-MATL*

Amorphous Magnesium-Fiber Reinforced Bone Cement with Enhanced Mechanical and Biological Properties

Aishwarya Vishwakarma, *Magnetism and Interface Physics, D-MATL*

Decoupling Pentacene Molecules on a Metallic Substrate: Insights into Charge Transfer, Spin Interactions, and Dynamics at the Interface.

Simon Wintersteller, *Chemistry and Materials Design, D-ITET*

Unravelling the Structure and Crystallization Mechanism of Amorphous Nanoparticle Phase-Change Materials

Julia Baumgartner, *Sustainable Food Processing, D-HEST*

Efficient Extraction of Lipid Droplets from Cell-Wall Deficient Microalgae with Pulsed Electric Fields

Wanwan Qiu, *Bone Biomechanics, D-HEST*

A Synthetic Dynamic Photoresin for Fast Volumetric Bioprinting of Functional Hydrogel Constructs

16.35 Flash Poster Presentations

16.50 Industry Presentations

17.15 Idea Pitches for a Novel Transdisciplinary Format

Election MaP Student Representative

17.40 Award Ceremony

18.00 Networking Reception (Apéro Riche)

Abstracts of Talks

Session 1: 09.00 – 10.00

Chair: Prof. Edoardo Mazza (Experimental Continuum Mechanics, D-MAVT)

Mitropoulou Ioanna

Non-Planar Layered Morphologies

Ioanna Mitropoulou [1], Olga Diamanti [2], Amir Vaxman [3], and Benjamin Dillenburger [1]

[1] Digital Building Technologies, D-ARCH, ETH Zurich
[2] TU Graz, Institute for Geometry, Department of Mathematics, TU Graz
[3] School of Informatics, Department of Computer Science, University of Edinburgh

Non-planar 3D printing of shells, enabled by the introduction of robotic arms in additive manufacturing, has the potential to revolutionize the production of complex structures with increased strength and reduced material usage. This innovation offers significant benefits in terms of design, efficiency, and sustainability. Its widespread applications include fabricating branching structures such as connection nodes or piping systems, printing structures on non-planar substrates, and producing highly curved surfaces. However, harnessing this potential is often hindered by the challenges involved in designing feasible non-planar print paths. To address this issue, this research introduces novel methodologies for designing non-planar print paths for robotic Fused Deposition Modeling (FDM) printing, specifically tailored for shell geometries, which take into account fabrication constraints and user input [1], [2]. To validate the effectiveness of these methodologies, fabricated prototypes of various scales are presented. Through the realization of non-planar path geometries, this research aims to facilitate advancements in the field of additive manufacturing.

[1] I. Mitropoulou, et. al. Print Paths Key-framing: Design for non-planar layered robotic FDM printing. Symposium on Computational Fabrication (2020).
[2] I. Mitropoulou, et. al. Nonplanar 3D Printing of Bifurcating Forms. 3D Printing and Additive Manufacturing (2022).

Non-planar FDM robotic 3D printing of branching structure. Photo credit: Ioanna Mitropoulou

Garau Paganella Lorenza

3D Hydrogel Platforms to Study Skin Cell Response to Hydrostatic Pressure

Lorenza G. Paganella [1,2], Celine Labouesse [2], Andreas Kourouklis [1], Costanza Giampietro [1], Mark Tibbitt [2], Edoardo Mazza [1]

[1] ECM, D-MAVT, ETH Zurich
[2] MEL, D-MAVT, ETH Zurich

Everyday cells are subjected to many mechanical stimulations, that elicit biological signalling cascades. Upon compression, tissues experience changes in fluid content, which lead to local variations in hydrostatic pressure. [1] These secondary stresses can influence cell physiological processes, as well as play a key role in pathological conditions, although the underlying mechanotransduction mechanisms remain unclear. [2] As cellular mechanoresponse is influenced by the microenvironment, with 2D culture often leading to a loss of native phenotype, robust 3D in vitro platforms that better recapitulate the *in vivo* context are needed to investigate these processes. [3] In our work we use natural collagen based 3D hydrogel scaffolds and synthetic poly(ethylene glycol) (PEG) peptide 3D hydrogels to encapsulate human dermal fibroblasts and investigate their biological response upon stimulation with a hydrostatic pressure bioreactor. Our data suggests that dermal fibroblast sense and respond to cyclic application (0.1 Hz) of low magnitude hydrostatic pressure (0.1 to 1.5 kPa) by upregulating *KI67* gene and protein expression, suggesting increased proliferation of cells. Higher magnitude cyclic hydrostatic pressure (0.1 to 5kPa) induced similar proliferative effects in collagen hydrogels, suggesting that the proliferative response is conserved not only within different 3D matrices, but also for different pressure magnitudes. Changes in proliferation were less significant with static pressure only, leading to the hypothesis that dermal fibroblasts are more prone to sense and respond to dynamic changes. In the future, we are interested in understanding more how the hydrogel environment influences the biological response by engineering our platforms to engage different mechanosensing elements of the cells.

[1] A. Ehret, et. al., Nature Communications. 8, 1002 (2017).
[2] J. Park, et. al., The EMBO Journal 41, 13 (2022).
[3] K. Maki, et al., Journal of cell science 134, 2 (2021).

Medany Mahmoud

Precision Guided Non-invasive Treatment of Aneurysms using Acoustic Robotics

Mahmoud Medany [1], Nitesh Nama [2], and Daniel Ahmed [1]

[1] Acoustic Robotics Systems Lab, Institute of Robotics and Intelligent systems, Department of Mechanical and Process Engineering, ETH Zurich, Switzerland
[2] Department of Mechanical Engineering, University of Nebraska-Lincoln, Nebraska, USA

CONFIDENTIAL

Marin Luca

Density Functional Theory Description of Xenon for Light Dark Matter Direct Detection

Luca Marin [1], Marek Matas [1], Einar Urdshals [2], Riccardo Catena [2] and Nicola Spaldin [1]

[1] Materials Theory, D-MATL, ETH Zurich
[2] Subatomic, High Energy and Plasma Physics Division, Department of Physics, Chalmers University of Technology

We present a detailed density functional theory (DFT) study of the electronic structure of atomic and liquid xenon, as a first step in quantifying the event rates in operating xenon-based detectors based on dark matter (DM) - electron scattering. Our main goal is to determine whether explicit modelling of the inter-atomic interactions in the liquid state changes the predicted event rates compared with current state-of-the-art models based on isolated Xe atoms [1].

[1] Riccardo Catena et al. “Atomic responses to general dark matter-electron interactions”. In: (Dec. 2019). arXiv:1912.08204 [hep-ph]

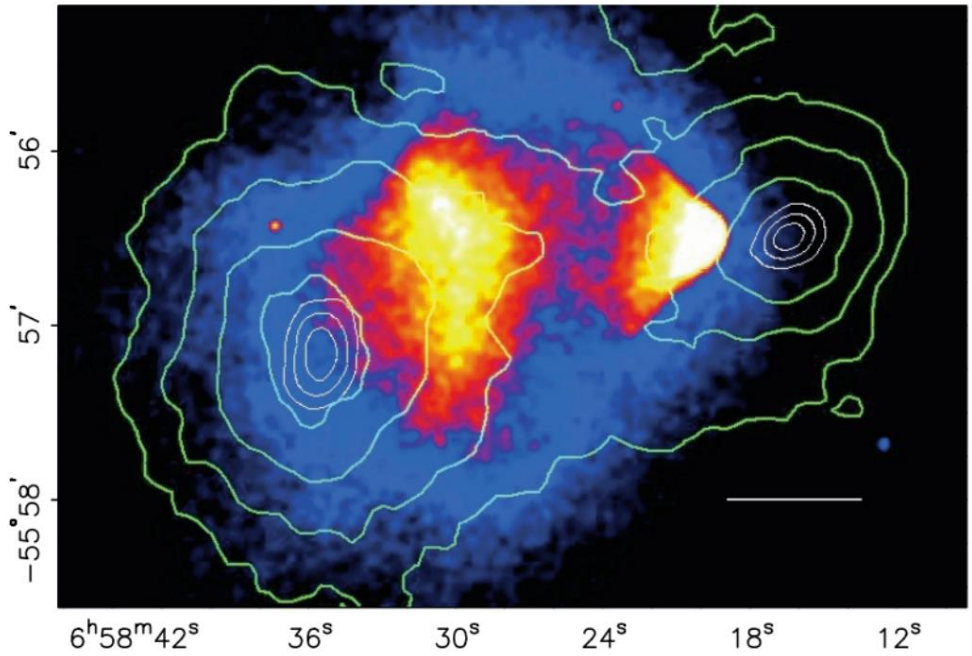


Figure from: Douglas Clowe et al. “A Direct Empirical Proof of the Existence of Dark Matter”. In: 648.2 (Sept. 2006), pp. L109–L113. doi: 10.1086/508162. arXiv: astro-ph/0608407 [astro-ph]

Efe Ipek

Nanoscale design of layered ferroelectrics for future smart electronics

Ipek Efe [1], Alexander Vogel [2], Elzbieta Gradasukaite [1], Marta D. Rossell [2], Manfred Fiebig [1] and Morgan Trassin [1]

[1] Multifunctional Ferroic Materials, D-MATL, ETH Zurich
[2] Electron Microscopy Center, Empa

The Internet of Things (IoT) era we are stepping into relies on the development of smarter and autonomous devices and sensors to support us in our everyday life in many aspects such as healthcare, productivity, energy management, and safety. Continuous power supply and corresponding electrical connections are needed, however, this limits the development of highly desired wireless technologies. Ferroelectric materials with spontaneous electric polarization can be used for the conversion of different external stimuli into electric signals and hence are promising candidates for self-powered, and self-sustained networks of electronic components for sensors, data storage, and microprocessors. Layered oxide ferroelectrics can further support exotic functionalities such as superconductivity and magnetoelectricity. However, integrating their complex crystal structures into application-relevant design has remained challenging, and routes to precisely monitor the growth and such functional systems have yet to be established. Here, we directly access the polarization dynamics of the layered ferroelectric model system Aurivillius $Bi_5FeTi_3O_{15}$ films during growth using nonlinear optics in situ. We identify the characteristic Aurivillius ordering of the electric dipoles along the growth direction and show how to incorporate various functionalities into the Aurivillius layered-crystal structure to expand the development of smart electronic device components.

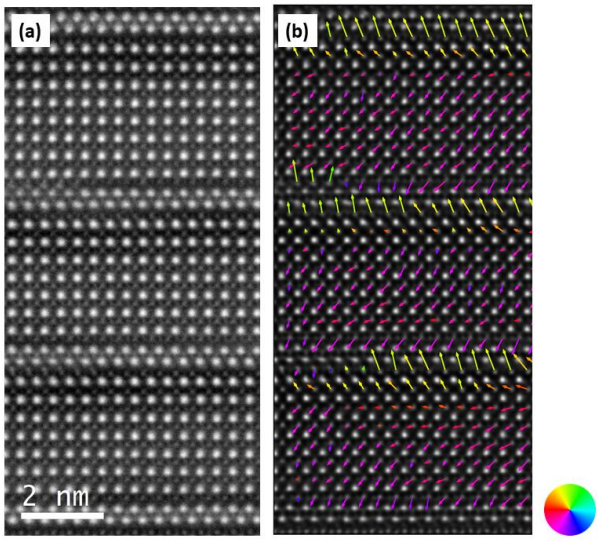


Figure 1) HAADF-STEM image of the grown hybrid Aurivillius thin film (a) and the corresponding polarization mapping revealing a ferrielectric-like dipole ordering calculated by the atomic displacements (b).

Session 2: 11.00 – 12.00

Chair: Prof. Ralph Müller (Bone Biomechanics, D-HEST)

Parkatzidis Kostas

Environmentally Friendly Light-driven Chemical Recycling of Polymers Back to Virgin Monomers

Kostas Parkatzidis [1], Athina Anastasaki [1]

[1] Laboratory of Polymeric Materials, Department of Materials, ETH Zurich.

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Müller Florence

A modular silica core-shell synthesis particle platform: rough, sticky and yet reversible colloidal gels

Florence J. Müller [1,2], Lucio Isa [2], Jan Vermant [1]

[1] Soft Materials, D-MATL, ETH Zurich
[2] Soft Materials and Interfaces, D-MATL, ETH Zurich

CONFIDENTIAL

Zimmermann Monika

Radiotherapy Enhancement by $Ti_3C_2T_x$ MXenes

Monika Zimmermann [1,2], Lukas R.H. Gerken [1,2], Shianlin Wee [3], Vera Kissling [2], Anna L. Neuer [1,2], Elena Tsolaki [1,2], Alexander Gogos [1,2], Maria R. Lukatskaya [3], Inge K. Herrmann [1,2]

[1] Nanoparticle Systems Engineering, D-MAVT, ETH Zurich
[2] Particles-Biology Interactions, Department of Materials Meet Life, Empa
[3] Electrochemical Energy Systems, D-MAVT, ETH Zurich

CONFIDENTIAL

Schmid Julian

Microscale Investigation on Interfacial Removal of Microfoulants from Soft Materials

Julian Schmid [1], Tobias Armstrong [1], Fabian Jau-Shiuen Dickhardt [1], SK Rameez Iqbal [1], Thomas M. Schutzius [1,2]

[1] MTSN, D-MAVT, ETH Zurich
[2] Department of Mechanical Engineering, University of California, Berkeley, CA 94720, USA

Unwanted deposition of organic and inorganic material on surfaces in an aqueous environment, known as particulate and crystallization fouling, is omnipresent in nature and technology and negatively affects the efficiency of water treatment, desalination, and energy conversion processes [1]. Currently, this problem is addressed primarily by active methods such as antiscalant additives or mechanical removal of the fouling layer; however, what is needed for sustainability are passive methods such as surfaces with inherent self-cleaning or anti-fouling properties. Previous work [2] on anti-fouling surfaces for important foulants like calcium carbonate has emphasized altering the surface energy and texture of rigid materials, neglecting to study bio-inspired compliant materials which exhibit exceptional interfacial properties and can incorporate intrinsic foulant-repellency. However, the precise role of the combined effects of substrate compliance, composition, and surface texture in an aqueous environment on foulant adhesion at the microscale are unknown. Here, we investigate the intertwined effects of shear flow, compliance, and surface texture on micro-foulant adhesion for a range of foulant sizes. For the study, we use a micro-scanning fluid dynamic gauge (μ-sFDG) setup which allows us to perform *in-situ* shear removal experiments for calcium carbonate and polystyrene micro-foulants on compliant anti-fouling surfaces. Guided by adhesion and fluid mechanics theory, and rational micro-engineering of the compliant materials we obtained first counterintuitive results showing that the compliant materials outperform the hard materials. The results of the work provide promising insight into the design of compliant interfacial materials facilitating high anti-fouling performance for resisting particulate and crystallization fouling in a wide range of industrial processes.

[1] J. Berce, et. al., *Processes 9*, 1356 (2021)
[2] G. Azimi, et. al., *Appl. Surf. Sci.* 313, 591–599 (2014).

Jafarabadi Ali

4D Printing of Recoverable Buckling-Induced Architected Iron-based Shape Memory Alloys

Ali Jafarabadi [1,2], Irene Ferretto [3], Maryam Mohri [2], Christian Leinenbach [3], Elyas Ghafoori [1], Eleni Chatzi [1]

[1] Structural Mechanics and Monitoring, D-BAUG, ETH Zurich
[2] Empa, Structural Engineering, Empa
[3] Empa, Advanced Materials Processing, Empa

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MaP Award 2023

13.30– 15.00

Chair: Prof. Lucio Isa (Soft Materials and Interfaces, D-MATL)

Rational Design of Nanoparticle Radioenhancers for Precision Radiotherapy

Dr. Lukas Gerken

Nanoparticle Systems Engineering, D-MAVT, ETH Zurich

Nanoparticle-based radio-enhancement has the prospect to improve cancer cell eradication by amplifying the damage caused by (x-ray) irradiation through the ejection of secondary particles (electrons) leading to further oxidative stress. Gold nanoparticles are a natural choice because of their high atomic number and biological compatibility and are therefore the most researched nanoparticles. However, due to the heterogeneous results and the lack in mechanistic understanding, these particle systems have not yet entered clinics. Nanoparticles based on more exotic hafnium dioxide have passed phase III clinical trials and most recently received European CE marking for treating locally advanced soft tissue sarcoma. There is increasing evidence that radio-enhancement efficacy does not solely rely on physical effects, which are strongest for high atomic number materials (Au, Hf), but involves a complex cascade of secondary reactions.

The current thesis presents key understandings of nanoparticles for the enhancement of radiotherapy. The impact of nanoparticle atomic number and the energy of the ionizing radiation source on nanoparticle radioenhancement is demonstrated in both simulations (digital twin model of a cell), as well as experimentally. The important role of radiocatalytic surfaces for the enhanced generation of hydroxyl radicals during radiotherapy is elaborated. Based on these comprehensive data, conclusions on the therapeutic performance of different nanoparticle properties can be drawn and nanoparticle design criteria can be extracted. The present work showcases the use of an interdisciplinary toolbox advancing the field, studying physical, chemical and biological contributions, thus enabling disentanglement and mechanistic understanding.

Ferroelectric Memristors for Neuromorphic Applications: Design, Fabrication, and Integration

Dr. Mattia Halter

Computational Nanoelectronics, D-ITET

Bio-inspired computing emerged as the forefront technology to harness the growing amount of data generated in an increasingly connected society. Dedicated hardware solutions are required to leverage its full potential, especially regarding power consumption and parallelism by co-locating memory and computing.

In the analog domain, the state of a synapse is emulated by a programmable electrical conductance. Using the ferroelectric polarisation switching to modulate the conductance promises a low power and high endurance operation due to its electrostatic nature.

First, the process development for the materials is reviewed. A Back-End-Of-Line compatible crystallisation of $HfZrO_4$ (HZO), a CMOS friendly and scalable material is demonstrated. Furthermore, the development of a semiconducting WO_x channel is presented, including the effect of the deposition method and processing conditions on its electrical properties.

In the second part, the developed materials are combined in a FeFET device: a simple gate-first device layout is designed and then used to establish a direct link between the ferroelectric polarisation and the channel conductance. The fine-grained domain structure of HZO leads to a programmable multi-state conductance. The device area, dynamic range and endurance called for improvement. The resulting second FeFET generation is a sub-µm size device with a quasi-continuous weight update. It is found that a fast, saturating ferroelectric effect and a slow, less saturating ionic drift and diffusion process are responsible for a multitime scale behaviour. The FeFET exhibits an excellent endurance and ferroelectric retention thanks to the good interface between the ferroelectric and the oxide channel. Simulating the classification of the MNIST dataset, results in an excellent accuracy of 88%, making it well suited for neuromorphic and cognitive computing.

New Polymerization and Post-Synthesis Strategies in On-Surface Synthesis

Dr. Amogh Kinikar

Magnetism and Interface Physics, Empa & D-MATL

The thesis, 'New polymerization and post-synthesis strategies in On-Surface synthesis,' significantly impacts surface science, organic chemistry, and nanomaterial synthesis. It addresses the challenge of synthesizing arylene-phenylene co-polymers, essential for organic FET devices, by presenting the first highly selective cycloaromatization reaction that produces phenylene rings from isopropyl substituents. Combining atomic-resolution images and density functional theory calculations, the research eluci-dates the reaction pathway, illustrating a translational approach to addressing scientific grand chal-lenges.

Aiming to develop better materials for the quantum revolution, the thesis introduces a new class of graphene nanoribbons called edge-functionalized zigzag graphene nanoribbons (EZGNRs). These materials enable the emulation of various 1D quantum physics phenomena to expand the undestand-ing of strongly-correlated electrons. Ultimately, these structures would contribute to the creation of improved quantum materials.

The thesis also overcomes a major limitation in on-surface synthesis, which typically requires inde-pendent molecular precursors for each selectively synthesized end-product. It demonstrates that chemically stable C-H bonds on graphene nanoribbon edges can be cleaved using chlorine, yielding dehydrogenated GNRs with radical sites on their edges. These reactive sites facilitate various chemi-cal reactions, allowing a single molecular precursor to produce multiple functionalized nanomaterials and significantly expanding the scope of surface chemistry.

Development and Application of Photosensitive Bioresins for 3D Biofabrication Strategies

From Volumetric Printing to Two-Photon Stereolithography

Dr. Riccardo Rizzo

Tissue Engineering and Biofabrication, D-HEST

Tissue Engineering is an interdisciplinary research field that brings together the principles of biology, chemistry, material science and engineering to repair and regenerate tissues and organs. In the thirty years from its foundation, tissue engineering has grown exponentially by embracing and fostering innovations from the most disparate research fields. In recent years, advances in three-dimensional (3D) biofabrication technologies have played a major role opening new, unprecedented avenues towards the generation of tissues and organs that accurately resemble native structure and functions. In particular, light-based 3D biofabrication is playing an increasingly important role. Leveraging various photochemical reactions, light can be used to gain unprecedented spatiotemporal control over material's physical, chemical and biological properties. My doctoral dissertation presents a series of works focused on exploiting the power of light for tissue engineering applications. The presentation will touch upon various projects, highlighting four main results: 1) Development of an optimized click-based photoresin and its first use for a novel biofabrication method called volumetric printing (VP), resulting in unprecedented printing speed and promising biological outcomes. 2) Convergence of VP and high resolution two-photon ablation to generate highly complex, organotypic, vasculature-like microfluidic constructs. 3) Development of a paradigm-shift photochemical strategy to crosslink photoresins without generating cytotoxic free-radicals. 4) Translatable light-based method to obtain human cartilaginous tissues with remarkable native-like composition, mechanical properties and anisotropic collagen deposition mimicking articular cartilage.

Session 3: 15.30– 16.30

Chair: Prof. Simone Schürle (Responsive Biomedical Systems, D-HEST)

Rich Andrea

Amorphous Magnesium-Fiber Reinforced Bone Cement with Enhanced Mechanical and Biological Properties

Andrea M Rich [1], Leopold Berger [1], Robin Deller [1], Niccoló de Berardinis [2], Benedikt Helgason [3], Gry Hulsart Billström [4], Stephen J Ferguson [3], Cecelia Persson [2], Jörg F Löffler [1]

[1] Metal Physics and Technology, D-MATL, ETH Zurich
[2] Division of Biomedical Engineering, Department of Materials Science and Engineering, Uppsala University, Sweden.
[3] Laboratory of Orthopedic Technology, Department of Health Sciences and Technology, ETH Zurich, Switzerland
[4] Department of Medical Cell Biology, Uppsala University, Sweden

Biodegradable bone cements are clinically deployed to fill voids and can be replaced by bone as they degrade [1]. Current ceramic bone cements are often unsuitable for load-bearing applications due to their brittle fracture at low stresses [2]. This could be improved by reinforcing the cement with randomly oriented short fibers [3]. In this work, a magnesium-fiber reinforced magnesium calcium phosphate cement demonstrated improved work of fracture, flexural strength, and degradation rate compared to the non-reinforced cement. Composite cements with randomly oriented, amorphous magnesium fibers were created with volume fractions of 10%, 13%, 15%, 18%, and 20%. Three-point bending tests were performed on cement with and without fibers. Fiber-reinforced cements showed increased work of fracture in all cases and improved flexural strength for 13% and 18% fibers. *In vitro* cell testing with pre-osteoblastic cells showed promising cell viability and proliferation, indicating good biocompatibility. To our knowledge, this is the first fully degradable composite bone cement reinforced with randomly oriented short fibers that maintains or improves flexural strength and stiffness while also improving ductility.

[1] W. Hettwer *et. al.,* APMIS 127:53-63 (2019).
[2] S.d.L. Schickert *et. al.,* Biomater. Sci. 8:4239-50 (2020).
[3] D.G. Petre *et. al.,* J. Tissue Eng. 28:141-59 (2022).

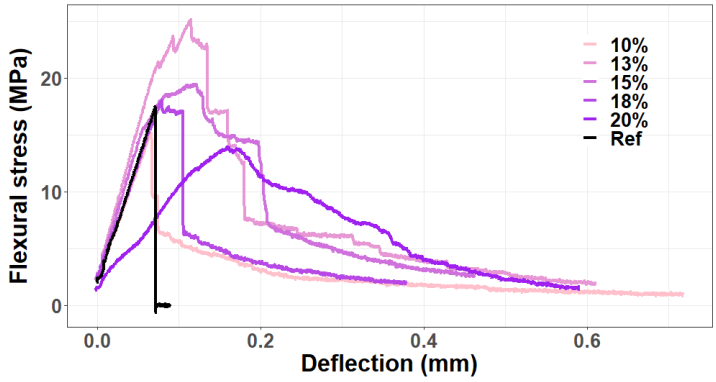

Fig. 1: Typical curves from three-point bending tests of reference and fiber-reinforced cements for tested fiber volume fractions of 10 to 20%.

Vishwakarma Aishwarya

Decoupling Pentacene Molecules on a Metallic Substrate: Insights into Charge Transfer, Spin Interactions, and Dynamics at the Interface.

Aishwarya Vishwakarma[1], Stepan Kovarik[1], Richard Schlitz[1], Dominic Ruckert[1], Pietro Gambardella[1], and Sebastian Stepanow[1]

[1] Magnetism and Interface Physics, Department of Materials, ETH Zurich

CONFIDENTIAL

Wintersteller Simon

Unravelling the Structure and Crystallization Mechanism of Amorphous Nanoparticle Phase-Change Materials

Simon Wintersteller[1], Olesya Yarema[1], Dhananjeya Kumaar[1], Florian M. Schenk[1], Olga Safonova[2], Vanessa Wood[1], Paula M. Abdala[3], Maksym Yarema[1]

[1] Institute for Electronics, D-ITET, ETH Zurich
[2] Bioenergy and Catalysis Laboratory, Energy and Environment Research Division, PSI
[3] Laboratory of Energy Science and Engineering, D-MAVT, ETH Zurich and PSI

CONFIDENTIAL

Baumgartner Julia

Efficient Extraction of Lipid Droplets from Cell-Wall Deficient Microalgae with Pulsed Electric Fields

Julia Baumgartner [1], Sing Teng Chua [2], Maylin Blunier [1], Fengzheng Gao [1], Michael Hans-Peter Studer [3], and Alexander Mathys [1]

[1] SFP, D-HEST, ETH Zurich
[2] Vignolini, Yusuf Hamied Department of Chemistry, University of Cambridge
[3] Studer, Energy-Engineering, Berner Fachhochschule

Microalgae are promising and more sustainable sources of edible lipids with high nutritional value [1]. Microalgal lipids are generally stored intracellularly as lipid droplets (LDs) [2] and are mainly extracted by organic solvents [3], which is not cost-effective and not environmentally friendly. Conventionally, whole LDs have been extracted with intense centrifugation of mechanically broken cells in suspension based on protocols for oleaginous plant materials [4]. However, suitable alternative processing strategies for the extraction of whole LDs from microalgae are not developed yet. In this study, LDs were aqueously extracted from cell-wall deficient *Chlamydomonas reinhardtii* upon applying a continuous microsecond pulsed electric field (PEF) treatment in a plate-plate treatment chamber. High voltage pulses were generated by a RUP6-15CL pulse generator (GBS Elektronik GmbH) connected to an external trigger (15 MHz FG300, Yokogawa Electric). 3 unipolar square-wave electric field pulses of 10 µs duration and 15 kV/cm electric field strength were applied to microalgae in growth medium (pH 7). After subsequent vortexing and centrifugation at 5000 g for 10 min, whitish turbid supernatants were obtained. Comparable sizes of intracellular and PEF extracted LDs were observed by fluorescent microscopy with the lipids stained by BODIPY 505/515, indicating that LD sizes (0.5 – 3 µm) were unaltered by PEF treatment. Total triglyceride extraction efficiency, measured by GC-FID, depended on culture age. PEF treatment is a promising and efficient technology for the extraction of LDs from cell-wall deficient microalgae. With PEF technology, whole microalgal LDs could be introduced to the food and biotech sector, supporting the transfer towards more sustainable food sources.

[1] C. Enzing et. al. JRC Scientific and policy reports (2014).
[2] H. Goold et al. Plant Cell Reports 34(4), 545-555 (2015).
[3] T. C. Adarme- Vega et al. Microbial Cell Factories 11(1) (2012).
[4] H. M. Nguyen et al. Proteomics 11(21) 4266-4273 (2011).

Qiu Wanwan

A Synthetic Dynamic Photoresin for Fast Volumetric Bioprinting of Functional Hydrogel Constructs

Wanwan Qiu [1], Jenny Gehlen [1], Margherita Bernero [1], Christian Gehre [1], Gian Nutal Schädli [1], Ralph Müller [1] and Xiao-Hua Qin [1]

[1] Institute for Biomechanics, D-HEST, ETH Zurich

Volumetric bioprinting (VBP) has emerged as a powerful tool enabling fast biofabrication of living hydrogel constructs in one step. However, existing photoresins that meet the physicochemical requirements of VBP are limited to thermo-responsive photosensitive gelatin derivatives of high polymer concentrations.[1] Here, we report a dynamic resin based on thiol-ene photo-clickable polyvinyl alcohol (PVA) and thermo-sensitive sacrificial gelatin for VBP of functional ultrasoft hydrogel constructs within 7-15 s.

Incorporating gelatin as a temporary network in the PVA resins enables the printability with low polymer concentrations down to 1.5%, providing a stress-relaxing environment (Figure 1A). Human mesenchymal stem cells (hMSCs) remained highly viable after printing (Figure 1B). However, their morphology showed remarkable differences in 1.5% PVA (soft) and 3% PVA (stiff) matrices, with longer protrusions in the soft matrix after 7 days (Figure 1C). We reason that the matrix viscoelasticity resulting from the temporary gelatin network facilitated fast cell spreading. Interestingly, single hMSCs self-organized into multicellular aggregates in alignment with the printed channels. Altogether, we developed a novel synthetic dynamic photoresin enabling fast VBP of functional hydrogel constructs.[2]

[1] P.N. Bernal, et al., Adv. Mater. 31, 1904209 (2019). [2] W. Qiu, et al., Adv. Funct. Mater., 2214393 (2023).

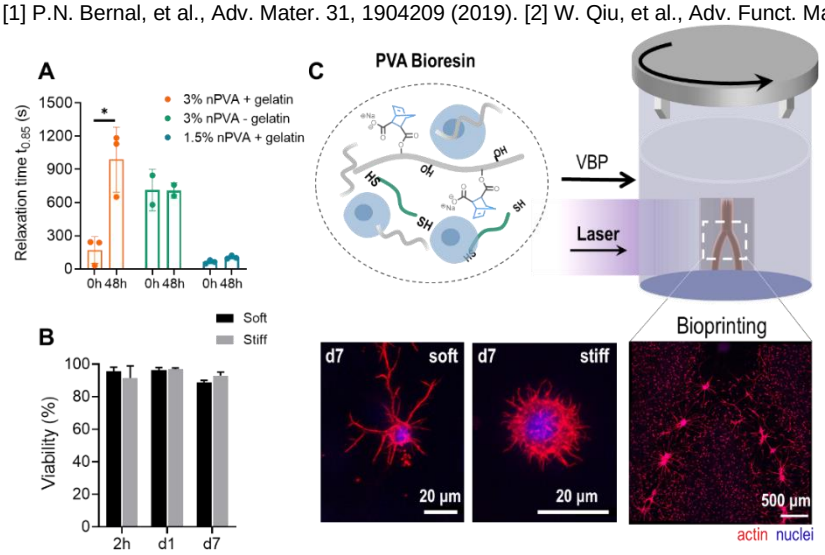

Figure 1. (A) The stress relaxation time (t0.85) of different hydrogel samples before (0 h) and after incubation in PBS at 37 °C for 48 h (48 h). Data presented as mean ± SD. Multiple paired t-test. *p = 0.0435 (n ≥ 2). (B) Quantification of hMSC viability at different time points. (C) Illustration of VBP and represensative cell morphologes in the bioprinted constructs at day 7.

Poster Presentations

No.	Name	Poster Title	Affiliation
1	**Wolf Morris**	Photoreversible Resins for Digitally Printed Protective Films	Macromolecular Engineering / DiPrintProtect, D-MAVT
2	**Abando Nerea**	Improved Sintering Performance with Nb As a Sintering Aid for Filament-Based Material Extrusion of NiTi	Nanometallurgy, D-MATL
3	**de Vries Anna**	Sunlight-Driven CO_2 Capture-Release Cycles by Photoacids with Enhanced Stability and Solubility in Binary Solvent Mixtures	Electrochemical Energy Systems, D-MAVT
4	**Bernet Marco**	Towards Multi-Material Spark Plasma Sintering	Advanced Manufacturing, D-MAVT
5	**Boggon Cameron**	Engineering Structured Polymicrobial Communities using bio-sCAPA	Soft Materials and Interfaces, D-MATL
6	**Boons Rani**	Dinoflagellate Bioluminescence as Base for Stress Sensing Living Materials	Complex Materials, D-MATL
7	**Studer Keno Ky R.**	Colloidal Particle Transport at a Liquid Interface Driven by Dynamic Interfaces	Soft Materials and Interfaces, D-MATL
8	**Shen Xueting**	Printing on particles: Combining Two-Photon Nanolithography and Capillary Assembly to Fabricate Multi-Material Microstructures	Soft Materials and Interfaces, D-MATL
9	**Niese Hannah**	Photon-Induced Near-Field Electron Microscopy in a Scanning Electron Microscope	Optical Materials Engineering, D-MAVT
10	**Dillinger Cornel**	A Versatile Acousto-Magnetic Responsive Composite Particle	Acoustic Robotics Systems Lab, D-MAVT
11	**Novaes-Silva Maria Clara**	Take a Deep Breath: The Impact of Mechanical Stresses on Lung Surfactants	Soft Materials, D-MATL
12	**Akhmetshina Tatiana**	Magnesium Corrosion and Lessons from High-Resolution 3D Data	Metal Physics and Technology, D-MATL
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14	**Bastek Jan-Hendrik**	Inverse Design of Deformable Mechanical Metamaterials via Video Denoising Diffusion	Mechanics and Materials, D-MAVT
15	**Veciana Andrea**	Confined Micellar Growth of COF-300 at the Nanoscale with Potential Applications in Microrobotics	Multi-Scale Robotics, D-MAVT
16	**Wang Hyun Suk**	Low-Temperature and Near-Quantitative Depolymerization of Polymers Synthesized by RAFT Polymerization	Polymeric Materials, D-MATL
17	**Kiwic David**	TiO_2 Nanoparticle Gelation at Neutral pH for Superior (Photo-)catalyst Materials	Multifunctional Materials, D-MATL
18	**Byloff Johanna**	Al2O3 Interlayer Influence on Mechanical and Interfacial Properties of Al Thin Films on Polyimide	Nanometallurgy, D-MATL

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19	**Del Campo Alexia**	Microfluidic Fabrication of Oscillation Shielding Coatings in Microbubbles for Selective Acoustic Interactions	Acoustic Robotics for Life Sciences and Healthcare, D-MAVT
20	**Bernhard Tim**	Comparing Performant Molecular Methods to Simulate Polymer Networks with Entanglements	Nanometallurgy, D-MATL
21	**Agrawal Prajwal**	Multi-scale Volumetric Printing	Acoustic Robotics for Life Sciences and Healthcare, D-MAVT
22	**Dreimol Christopher**	Iron-Catalyzed Laser-Induced Graphitization: A Novel Approach to Produce Sustainable, Bio-Inspired Electrodes with Tunable Iron Phases	Wood Materials Science, D-BAUG
23	**Scherrer Simon**	Rolling or Sliding? Characterising Micro-Particle Motion and Friction	Soft Materials and Interfaces, D-MATL
24	**Boolakee Oliver**	Lattice Boltzmann for Linear Elastic Solids	Computational Mechanics, D-MAVT
25	**Boev Dimitar**	Microscope-Assisted Acoustic DLP (Bio-)printing	Acoustic Robotics for Life Sciences and Healthcare, D-MAVT
26	**Klipp Alexander**	Enhanced Transfection by Release of an Endosomal Escape Mediating Protein	Drug Formulation & Delivery, D-CHAB
27	**Pereira Martendal Caroline**	Unraveling and Refining Co-Processability of Metallic Feedstock in Multi-Material Laser Powder Bed Fusion	Advanced Manufacturing, D-MAVT
28	**Niggel Vincent**	Imaging the Motion of Colloids in Dense Suspensions Under Shear	Soft Materials and Interfaces, D-MATL
29	**Góra Michał**	Surface Force on Nano-Porous Materials	Advanced Fibers, Empa
30	**Balciunaite Aiste**	Taking Topographical Cues from 2D to 3D: Contractile Skeletal Muscle Constructs Engineered with 3D Topography in Photopolymerizable Bioink	Soft Robotics, D-MAVT
31	**Kavas Baris**	Interlayer Temperature Stabilization via Closed-Loop Feedback Control in Laser Powder Bed Fusion	Advanced Manufacturing, D-MAVT
32	**Albert Cristhiana**	Corrosion Kinetics of Steel in Carbonated Pore Solutions	Durability of Engineering Materials, D-BAUG
33	**Deng Zhikang**	Effect of Temperature on Glass to Iron-based Shape Memory Alloy Adhesive Shear Joints	Steel and Composite Structures, D-BAUG
34	**Ruckert Dominic**	Detection and Excitation of Single Atomic Spins in a Scanning Tunneling Microscope	Magnetism and Interface Physics, D-MATL
35	**Verbeek Xanthe**	Hidden Order in Cr_2O_3 and α-Fe_2O_3 as a Predictor for Exotic Magnetic Behavior	Materials Theory, D-MATL
36	**Kercher Niklas**	Van der Waals Materials for Spintronics	Magnetism & Interface Physics, D-MATL

No.	Name	Poster Title	Affiliation
37	**Glauser Yannick**	Inverse Design of Optical Fourier Surfaces	Optical Materials Engineering, D-MAVT
38	**Dezauzier Raphael**	A Microfluidic Platform for the Formation of Spheroids for Personalized Cancer Treatment	Bioanalytics Group, D-BSSE
39	**van Schie Laura**	Imaging Domain Walls in RE-TM Ferrimagnetic Alloys via NV Magnetometry	Magnetism and Interface Physics
40	**Wohlwend Jelena**	Generating a full gamut of structural colors based on self-organized dielectric nanocup metasurfaces	Nanometallurgy, D-MATL
41	**Monti Chiara**	A New Al-Cu Alloy for Laser Powder Bed Fusion (LPBF) developed via Ultrasonic Atomization	Advanced Manufacturing, D-MAVT
42	**Achatz Julia**	Revolutionizing Roundwood Sorting: A Novel CNN-based Recommendation System for Improved Quality and Species Sorting with Image and Numerical Data	Wood Materials Science, D-BAUG
43	**Choi Young**	Stretch Limits and Damage of Endothelial Monolayers	Experimental Continuum Mechanics, D-MAVT
44	**Tao Siyuan**	An Injectable Living Hydrogel With Encapsulated Probiotics To Fight Against Pathogen Infections In Wounds	Biointerfaces, Empa
45	**Antonopoulou Maria-Nefeli**	Concurrent Control Over Sequence and Dispersity in Multiblock Copolymers	Polymeric Materials, D-MATL
46	**Greitens Christina**	BRET-Assay for Tracking Transfected Plasmid DNA in Cells	Drug Formulation and Delivery, D-CHAB
47	**Hofmann Marco**	Pulse Shaping Strategies for Efficient Spin-Orbit Torque Switching of Magnetic Tunnel Junctions	Magnetism and Interface Physics, D-MATL
48	**Zhang Zhiyuan**	SonoTransformers: Acoustically Actuated Ultrafast Shape Morphing Micromachines	Acoustic Robotics Systems Lab, D-MAVT
49	**Bernhard Stéphane**	Redox Responsive Nanogels for Intracellular Drug Delivery	Macromolecular Engineering, D-MAVT
50	**Born Friederike**	Microfluidic Platform to Visualize and Quantify Bacterial Response to Dynamic Drug Treatments	Bioanalytics Group, D-BSSE
51	**Cipolato Oscar**	Nanoparticle-Enhanced Laser Tissue Soldering	Nanoparticle Systems Engineering, D-MAVT
52	**Töpfer Ueli**	Controlling Self-Propulsion of Micro-Swimmers with Light	Soft Materials and Interfaces, D-MATL
53	**Tošić Tara**	Magnetic Frustration in Materials: the What, the Why, and the How of Simulation	Materials Theory, D-MATL
54	**Menétrey Maxence**	Nanodroplet Flight Control in Electrohydrodynamic Redox 3D Printing	Nanometallurgy, D-MATL

Abstracts of Posters

1 Wolf Morris

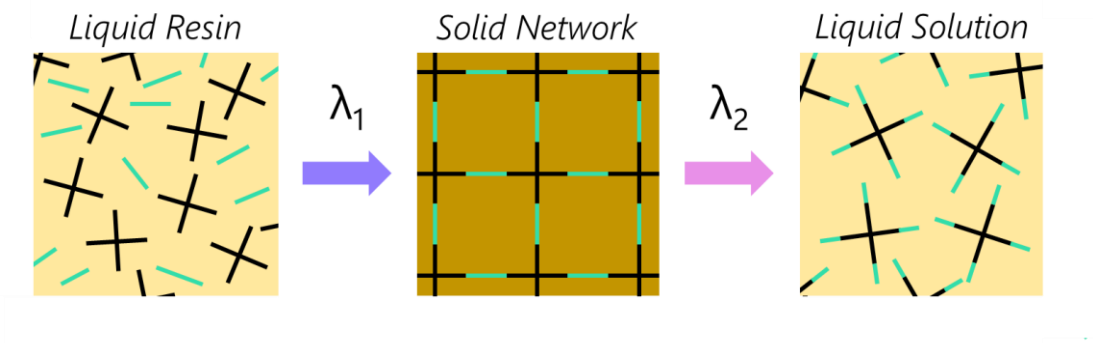
Photoreversible Resins for Digitally Printed Protective Films

Morris Wolf [1] and Mark W. Tibbitt [1]

[1] Macromolecular Engineering / DiPrintProtect, D-MAVT, ETH Zurich

The Swiss watch industry relies on handcrafted excellence. While precision manufacturing remains at the industrie's core, advanced materials and processes can complement some of the manual manufacturing steps. One such step is the application of resins (lacquers) onto dials and other metal parts that serve as temporary masks against mechanical and chemical processing. The DiPrintProtect project, in collaboration with EMPA and EPFL, aims to facilitate a digital printing process by developing a printable ink based on a reversible photo-polymer that can be cured (hardened) with light and removed later via irradition with a second wavelength of light without leaving traces. Our approach is based on a thiol-ene resin with a photodegradable cross-linker. While a suitable photoinitiator initates the cross-linking through thiol-ene click chemistry at 405nm UV light, the photodegradable cross-linker degrades the network by cleaving under irradiation with UV light at 365nm. A first ortho-nitrobenzyl (oNB)-diene cross-linker was synthesized following literature [1]. Currently, the cross-linker is modified to combine efficient cleavage capability through better quantum yield and red-shifting of absorbance with the desired properties of the final resin including printability. In addition, further pathways to achieve photo-reversibility are explored.

[1] S.V. Radl, et. al., Polym. Chem. 2017, 8, 1562-1572.



Through thiol-ene chemistry, a photoreversible network is formed after irradiation at λ1 that de-cross-links by breaking the *o*NB-diene cross-linker (green) after irradiation at λ2.

2 Abando Nerea

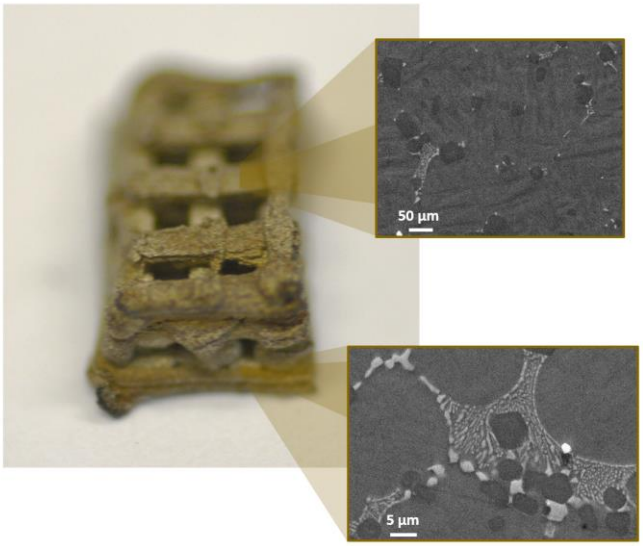
Improved Sintering Performance with Nb As a Sintering Aid for Filament-Based Material Extrusion of NiTi

Nerea Abando [1], Amir Hadian [2], Frank Clemens [2] and Ralph Spolenak [1]

[1] Nanometallurgy, D-MATL, ETH Zurich
[2] High Performance Ceramics, Smart Ceramic Processing, Empa Dübendorf

Research on additive manufacturing of active materials, materials that respond to external stimuli, is exponentially growing due to their extraordinary functional properties. Among different classes, shape memory alloys such as NiTi show exceptional recoverable deformations triggered by temperature as a consequence of an austenitic phase transformation [1]. The outstanding properties of these materials can be further enhanced by geometry, where the global deformation is increased while keeping the local within limits. Filament based material extrusion additive manufacturing offers the design freedom necessary to produce intricate parts with a low environmental footprint. However, the densification of the material is often incomplete due to processing steps intrinsic to this technique, thus hindering the actuation of the shape memory alloy. In contrast to recent studies focusing on the binder constituents [2], here we explore the use of Nb as a sintering aid for overcoming this challenge. Porosity is reduced due to the formation of the NiTiNb eutectic during liquid phase sintering.

[1] J. Van Humbeeck et al., Endeavour 15, 4 (1991)
[2] M. Wagner et al., Addit. Manuf. 49 (2022)



Printed and sintered NiTiNb scaffold with magnified SEM images showing the needle-like martensitic microstructure and the lamellar eutectic phase.

3 de Vries Anna

Sunlight-Driven CO_2 Capture-Release Cycles by Photoacids with Enhanced Stability and Solubility in Binary Solvent Mixtures

Anna de Vries[1], Kateryna Goloviznina[2], Manuel Reiter[1], Mathieu Salanne [2,3], Maria Lukatskaya[1]

[1] Electrochemical Energy Systems, D-MAVT, ETH Zurich
[2] Physicochimie des Électrolytes et Nanosystèmes Interfaciaux, CNRS, Sorbonne Université
[3] Institut Universitaire de France (IUF), 75231 Paris, France

Rapid rise of atmospheric CO_2 levels require that carbon capture technologies must become more affordable; there is an urgent need for innovations beyond present-day energy intensive regeneration processes such as temperature of pressure swing [1]. Instead, pH-swing - i.e. cycling between high pH and low pH during abs- and desorption respectively - is a promising low energy alternative for CO_2 release as it runs at ambient conditions [2]. Controlled and reversible acidification of a solution can be achieved with photoacids.

Photoacids are organic molecules that release protons (H^+) under illumination, providing spatiotemporal control of acidity (pH). Such light-driven pH switches offer the ability to cyclically alter pH of the medium that is highly attractive for a wide variety of applications such as CO_2 capture, drug release and sensors [3]. Although photoacids such as protonated merocyanine enable fully reversible pH cycling in water, they have a limited chemical stability against hydrolysis (<24 hours) [4]. Moreover, these photoacids have low solubility and provide only a small pH jump. In this work we introduce a simple pathway to dramatically increase stability and solubility of photoacids by tuning their solvation environment in binary solvent mixtures. We show that a preferential solvation of merocyanine by aprotic solvent molecules results in a 10-fold increase of light-released protons and a stable and large pH modulation for >350 hours when compared to the behavior in pure water. Our results suggest that a very high stability of merocyanine photoacids can be achieved in the right solvent mixtures, offering a way to bypass complex structural modifications of photoacid molecules and serving as the key milestone toward their applications.

[1] S.E. Renfrew, et. al., ACS Catalysis, 10, 21 (2020)
[2] S. Jin, et. al., Nat. Comm., 13.1, 1-11 (2022)
[3] C. Berton, et. al., Chem. Sci., 11, 8457-8468 (2020)
[4] N. Abeyrathna, et. al., J. Phys. Org. Chem., 30.8: e3664 (2018)

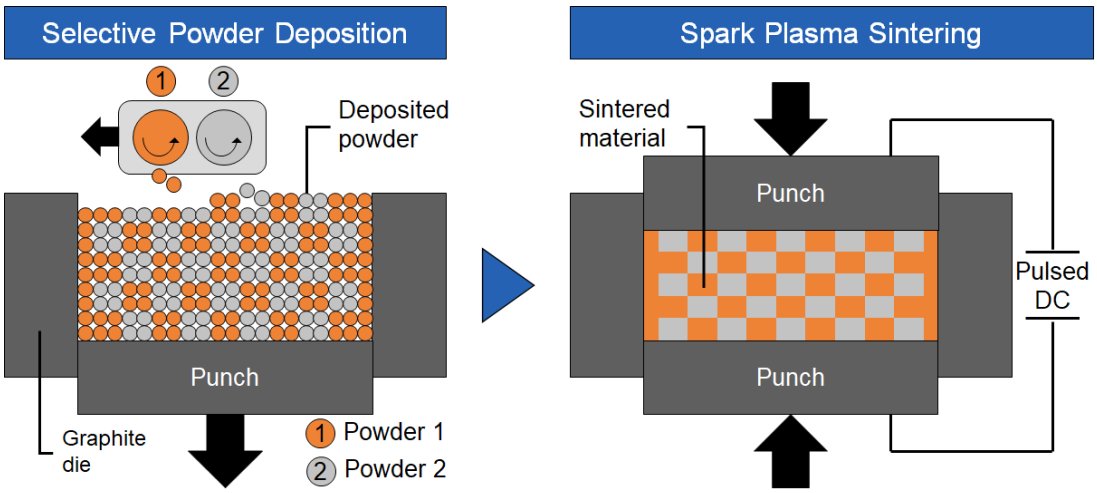
4 Bernet Marco

Towards Multi-Material Spark Plasma Sintering

Marco Bernet [1], Léa Deillon [1], and Markus Bambach [1]

[1] Advanced Manufacturing, D-MAVT, ETH Zurich

Field-Assisted Sintering Technology also known as Spark Plasma Sintering (FAST/SPS) consolidates materials using a high pulsed direct current and low voltage while applying mechanical pressure. The grain size and microstructure of the powder is preserved due to the short process time enabling the study of novel nano-crystalline and ultrafine grain sized materials. However, the shape of the final product is still mostly limited to disk-shaped objects, and the interface orientations for multi-materials are oftentimes only achieved by consecutive filling of different powders. Only few publications have yet addressed this problem for the SPS process so far, with only minor improvements in terms of material and design freedom. A novel process route that enables more complex interfaces and designs in the FAST/SPS by selective deposition of two powders layer-by-layer inside the tool die is presented. In order to co-process materials with different melting points together, the sintering behavior of the two metals must be considered such that full density in both materials is achieved after sintering. The concept of Master Sintering Curve (MSC) assists in finding suitable co-processing parameters for the desired material combination. Initial efforts to understand the influence of powder size and sintering process parameters on MSC to help the finding of co-processing parameters and strategies for metal powders with dissimilar melting points will be presented.



Schematic of the process route to create more complex geometries or patterns for the FAST/SPS setup. Metal powders are selectively deposited within a graphite die prior to by consolidation of the deposited structure using Spark Plasma Sintering.

5 Boggon Cameron

Engineering Structured Polymicrobial Communities using bio-sCAPA

Cameron Boggon [1], Jeruscha Baum [2], Srikanth Mairpady Shambat [2], Annelies Zinkernagel [2], Silvio Brugger [2], Eleonora Secchi [3], and Lucio Isa [1]

[1] Laboratory of Soft Materials and Interfaces, D-MATL, ETH Zurich
[2] Department of Infectious Diseases and Hospital Epidemiology, University Hospital Zurich
[3] D-BAUG, ETH Zurich

The majority of bacteria live in structured, polymicrobial, surfaced-attached bacterial communities which are difficult to mimic in laboratory settings and yet likely play a critical role in microbial ecology. We are developing in-vitro methods based on microfluidics for manipulating entire bacterial communities (>10^5 cells) such that we can carefully control, at the single-cell level, structural features of the community like cell-cell distance, initial bacterial concentration, the number of species present and the nutrient environment they are grown in. Our approach, which we call bio-sCAPA, involves selectively patterning single bacterial cells into targeted geometries. We will show how we have used this platform to perform single-cell characterisation of antibiotic tolerant Staphylococcus aureus, highlighting that *S. aureus* cells tolerant to antibiotic killing are characterised only by prolonged lag-time and not growth rate heterogeneity. This can be used as a clinical indicator to distinguish antibiotic tolerance from antibiotic resistance, and therefore help inform treatment strategies. Secondly, we will show ongoing work studying two commensal organisms in the human nose microbiome that are negatively associated with *S. aureus*. We will demonstrate direct inhibition of *S. aureus* by these commensals and how we are leveraging bio-sCAPA to study the characteristics of a nose microbiome that forms stable communities which resist *S. aureus* colonisation.

6 Boons Rani

Dinoflagellate Bioluminescence as Base for Stress Sensing Living Materials

[1] Complex Materials, D-MATL, ETH Zurich
[2] Cellulose & Wood Materials Laboratory, Materials Meet Life, Empa
[3] D-HEST, ETH Zürich

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7 Studer Keno Ky R.

Colloidal Particle Transport at a Liquid Interface Driven by Dynamic Interfaces

Keno Ky R. Studer [1], Lucio Isa [1] and Federico Paratore [1]

[1] Soft Materials and Interfaces, D-MATL, ETH Zürich

Colloids confined at liquid interfaces play a key role in many natural processes and in several technological applications, such as emulsification, biofilm formation and water remediation. Whereas most studies investigated particle dynamics and assembly on flat or static curved interfaces [1], the transport of colloidal particles at liquid interfaces with dynamically changing topographies remains essentially unexplored. Colloids with different surface properties, e.g. shape, surface chemistry and roughness, induce different interfacial deformations [2], which under a given interface topography, will give rise to different capillary forces, thus experiencing different transport regimes. We are currently developing a platform for reconfigurable fluid interfaces that uses moving micropillars to mechanically deform a water-oil interface, and leverage this to characterize the motion of families of colloids. As an example, we demonstrated the emergence of a torque on quadrupolar particles upon experiencing a change in interfacial deformation from convex to concave, leading to the realignment of the particle with the curvature gradient. At the MaP symposium we will present our latest findings and discuss future applications for colloidal particle separation at liquid interfaces.

[1] I. B. Liu, et. al., Phil. Trans. R. Soc. A, 374 (2015)
[2] L. Botto, et. al., Soft Matter, 8, 9957 (2012)

8 Shen Xueting

Printing on particles: Combining Two-Photon Nanolithography and Capillary Assembly to Fabricate Multi-Material Microstructures

Steven van Kesteren*[1], Xueting Shen*[1], Michele Aldeghi [1], Lucio Isa [1]

[1] Soft Materials and Interfaces, D-MATL, ETH Zürich
[2] IBM Research, Zürich

Increasing complex colloidal structures are being developed to be building blocks for new materials. Additive manufacturing at micron- and nanoscale have seen an increased used to suite the demand for more elaborate colloidal structures. However, the fabrication routes demonstrated in previous works has limitations in the choice of material and the fabrication of micron-scale composite structures remains as a challenge. Here, we combine the directed assembly of colloidal particles with sequential capillarity-assisted particle assembly (sCAPA) and two-photon direct laser writing (DLW). We use DLW fabricate the novel 3D micro-templates for the capillary assembly of differently-sized colloids. Furthermore, we use DLW to link well-defined arrangements of polystyrene or silica particles made with sCAPA. We demonstrate novel approaches to fabricating multi-material lines, waves, lattices and various shapes of micro-structures in large quantities. The patterned particles are selectively linked together in arbitrary shapes with a commercial photo-resist (IP-L or IP-PDMS) and dispersed in water. The flexibility of our method allows the combination and patterning of a wide range of materials enabling the fabrication of complex configurations on the sub-micron scale. [1]

[1] van Kesteren*, Shen*, Aldeghi, Isa. Advanced Materials (2023)

* equal contributions

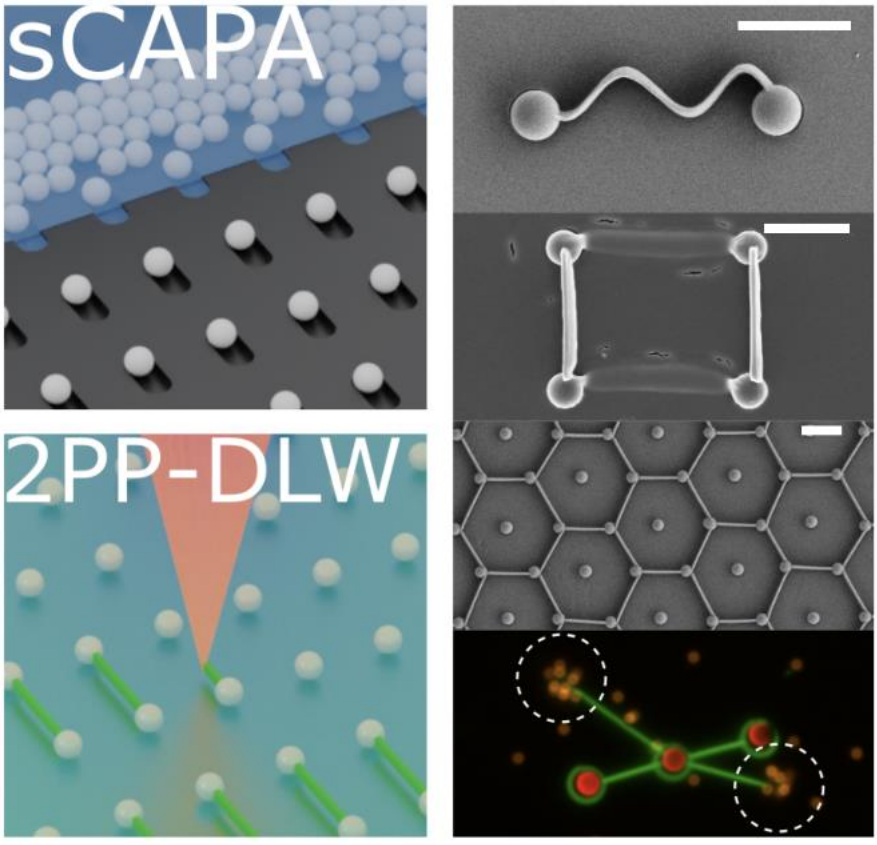


Figure: The combination of capillary assembly of colloidal particles and t w o - p h o t o n n a n o - 3 D printing allows the easy integration of multiple functional materials into complex 1D, 2D, and 3D-microstructures (A- C). This flexible

method enables the fabrication of wide range of (soft) microrobots, for example magnetically-controlled “micromachines”, which can capture and release particles in solution (D). Scale bars are 5 microns in length.

9 Niese Hannah

Photon-Induced Near-Field Electron Microscopy in a Scanning Electron Microscope

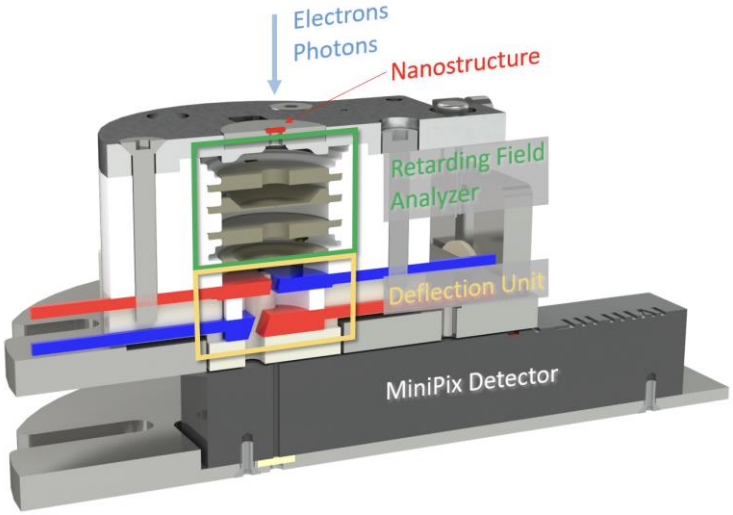
Hannah Niese [1,2], Matthias Liebtrau [1], and Albert Polman [1]

[1] Photonic Materials Group, Center for Nanophotonics, AMOLF
[2] Optical Materials Engineering, D-MAVT, ETH Zurich

The interaction of free electrons with light and matter offers new ways to characterize materials, and in particular nanophotonic systems at attosecond time and nanometer length scales over an ultra wide spectral range.[1] When swift electrons pass through a photon-induced near-field of a nanostructure, PINEM (Photon-induced near-field electron microscopy) can be observed, where the electron interacts with the near-fields and gains or loses energy quanta of the photon.[2] We worked on a setup for energy-resolved single-electron detection to measure PINEM with non-relativistic electrons in a Scanning electron microscope (SEM).

We modified and characterized a Retarding Field Analzyer (RFA) in experiments and simulations, which revealed an intrinsic energy resolution down to 100meV for incident electron energies of 4-6 keV. We introduce a silicon-based single-electron detector that can detect extremely small electron signals down to an effective beam current on the order of a few hundred attoamperes, but also detects signal from the laser in the setup. To block laser light from reaching the sensor surface and thus obscuring the electron signal, we design and test a deflection unit that only allows electrons through to the sensor. Nanostructures that can be used to show PINEM in our experimental conditions were simulated using Finite Difference Time-Domain (FDTD) methods, and PINEM coupling parameters and expected PINEM spectra were calculated.

[1] F. G. De Abajo. Reviews of modern physics, 82 (1):209, 2010.
[2] B. Barwick, D. J. Flannigan, and A. H. Zewail. Nature, 462(7275):902–906, 2009.



Overview of the detection system, consisting of the nanostructure, Retarding Field Analyzer and Deflection Unit and the MiniPix Detector.

10 Dillinger Cornel

A Versatile Acousto-Magnetic Responsive Composite Particle

Cornel Dillinger [1], Justin Knipper [1], Nitesh Nama [2], and Daniel Ahmed [1]

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[2] Nama Lab, Mechanical Engineering, University of Nebraska-Lincoln

CONFIDENTIAL

11 Novaes-Silva Maria Clara

Take a Deep Breath: The Impact of Mechanical Stresses on Lung Surfactants

Maria Clara Novaes-Silva [1], Mariana Rodriguez-Hakim [1,2] and Jan Vermant [1]

[1] Soft Materials, D-MATL, ETH Zurich
[2] Laboratorio de Sistemas Complejos, Departamento de Fisica Fundamental, UNED

Lung surfactants are known to decrease the surface tension in the lungs through the tight packing of lipids at the interface. For this reason, a complex interface might be formed, where the interfacial properties are not only governed by a state variable, but also by extra mechanical stresses [1]. In this work, we investigate this hypothesis by studying the impact of relevant strains and strain rates on the surface stress of lung surfactants with a rising bubble setup and a radial trough. We conclude that the interface is indeed complex with the extra stresses playing a fundamental role in lowering the surface stress. With this conclusion, we discuss the analysis for the rising bubble which, in this case, requires a generalized Young-Laplace equation. Moreover, we compare the dilatational moduli of the different techniques, concluding that, for the rising bubble, shear at the pinning point affects significantly the results.

[1] E. Hermans, et. al., Soft Matter, 11, 8048 (2015).

12 Akhmetshina Tatiana CONFIDENTIAL

Magnesium Corrosion and Lessons from High-Resolution 3D Data

Tatiana Akhmetshina [1], Robin E. Schäublin [1], Andrea M. Rich [1], Wolfgang Rubin [1], Nicholas W. Phillips [2], Leopold Berger [1], Jörg F. Löffler [1]

[1] Metal Physics and Technology, D-MATL, ETH Zurich
[2] Paul Scherrer Institute (PSI), Switzerland

13 Sobczyk Aleksandros

Algorithms and Hardness for Ab Initio Calculations

Aleksandros Sobczyk [1,2], Marko Mladenovic [1], and Mathieu Luisier [1]

1] Integrated Systems Laboratory, D-ITET, ETH Zurich
[2] AI for Scientic Discovery, Accelerated Discovery and AI, IBM Research Zurich

We revisit computational problems arising in ab initio calculations. Given a Hamiltonian and an overlap matrix describing the orbital interactions in a system of atoms, we study two problems: the first one is to compute the Fermi level of the system and the second one to compute the charge density over a given set of grid points. Classically, both of those problems can be solved in time that scales cubically with the system size via diagonalization of the corresponding matrices, which can be prohibitive in practice for realistic systems. For sparse systems (i.e. when long range interactions decay exponentially) there exist heuristic methods that achieve better scaling at the cost of introducing numerical errors. A known limitation of such methods is that in order to achieve good performance the errors can grow arbitrarily. In this work we consider upper and lower bounds regarding the computational complexity of those two problems. For the computation of the charge density, we show that if we have an oracle that can provide a “guess” for the Fermi level, then there exists a randomized algorithm that can provably approximate the charge density over a set of grid points with high probability in time that scales nearly linearly to the system size. For the computation of the Fermi level, we show that it is at least as hard as the so-called “matrix rank certification problem”, which in turn is conjectured to be as hard as standard diagonalization.

14 Bastek Jan-Hendrik

Inverse Design of Deformable Mechanical Metamaterials via Video Denoising Diffusion

Jan-Hendrik Bastek [1] and Dennis M. Kochmann [2]

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The accelerated inverse design of nonlinear material properties, i.e., identifying a material with a given stress-strain response over a finite deformation path, holds great potential for addressing pressing challenges in, e.g., soft robotics, biomedical implants, and energy absorption. Machine learning models have received significant attention and demonstrated success in obtaining such highly nonlinear mappings, though they have typically been applied to linear properties, such as the directional Young's modulus, and rarely to more complex settings as the ones mentioned above [1].
We here address this challenge and present a novel framework that leverages recent advances in generative deep learning models. Specifically, we develop a *video* diffusion model [2] trained on the full-field data of periodic stochastic structures obtained via finite-element (FE) simulations to predict the deformation and stress response of these structures in the finite-strain regime, which can identify novel structures with highly challenging mechanical target responses.

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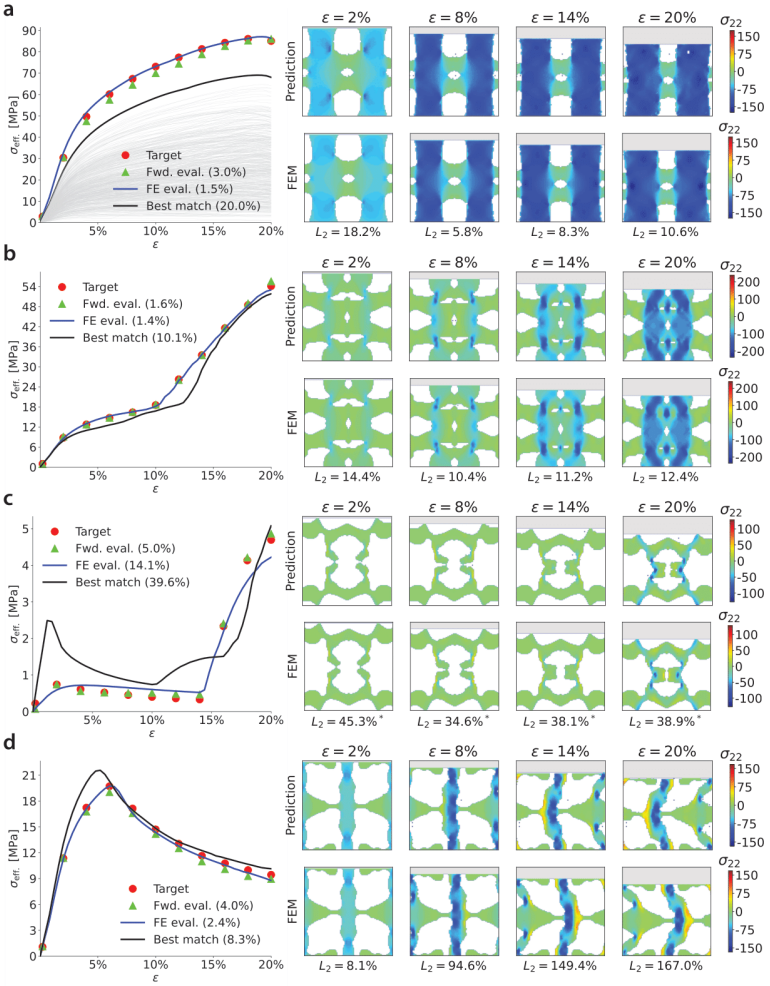

Metamaterial synthesis for non-trivial stress-strain responses and comparison to FE ground truth.

15 Veciana Andrea

Confined Micellar Growth of COF-300 at the Nanoscale with Potential Applications in Microrobotics

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CONFIDENTIAL

16 Wang Hyun Suk

Low-Temperature and Near-Quantitative Depolymerization of Polymers Synthesized by RAFT Polymerization

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The chemical recycling of plastics (e.g. Plexiglas) to regenerate monomer is an attractive route to a circular economy.[1] However, conventional pyrolysis requires elevated temperatures in excess of 400 °C to achieve this goal and is prone to side reactions. Here, we demonstrate the depolymerization of various types of polymethacrylates (linear, bulky, cross-linked, and functional) prepared by reversible addition–fragmentation chain-transfer (RAFT) polymerization.[2] Our approach utilizes the high end-group fidelity of RAFT polymers to generate chain-end radicals at 120 °C, which trigger a rapid unzipping of both conventional and bulky polymers. We demonstrate near-quantitative (up to 92%) and a catalyst-free depolymerization, and show that the product can be used to reconstruct the original linear polymer or create an entirely new insoluble gel that can also be subjected to depolymerization. Furthermore, even polymers with thermally unstable side chains could be depolymerized back to the original monomer, highlighting the importance of achieving depolymerization at low temperatures.[3]

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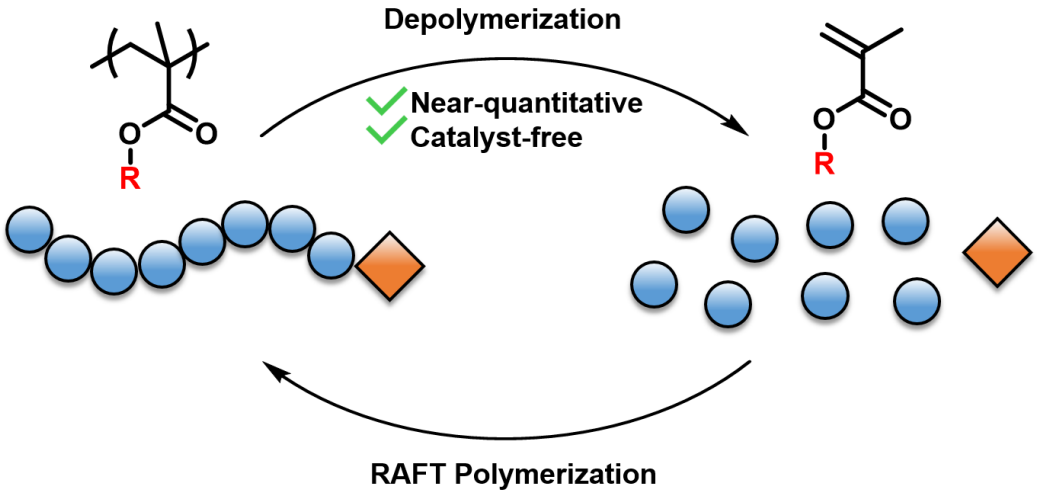

Figure: Near-Quantitative and catalyst-free depolymerization of RAFT-polymethacrylates.

17 Kiwic David

TiO_2 Nanoparticle Gelation at Neutral pH for Superior (Photo-)catalyst Materials

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High activity catalysts are essential to reducing the energy and resource consumption of the chemical industry. The catalyst activity typically scales with the available surface area. Aerogels are among the materials with the largest possible surface area. The utilization of aerogels as catalysts is understudied, since only very limited materials chemistries have been available through conventional sol-gel methods. Furthermore, sol-gel derived aerogels typically suffer from poor crystallinity which is often detrimental to catalytic activity and stability.

Superior aerogels can be produced by the nanoparticle gelation method. Hereby crystalline nanoparticles are synthesized and subsequently gelled to obtain highly crystalline aerogels. For example, aerogels produced from TiO2 nanoparticles, show similar specific surface areas as classical sol-gel derived aerogels, while additionally displaying excellent translucency. These beneficial optical and structural properties encourage their use in (photo-)catalyst materials. It has been shown that TiO2 nanoparticles can be gelled together with other co-catalyst materials such as Pd nanoparticles to improve catalytic properties. [1] These noble metals are costly and have a high environmental impact. To further broaden the spectrum of possible material combinations and circumvent the use of noble metals, the method needs to be further improved.

Before inducing gelation, the TiO2 nanoparticles need to be colloidally dispersed in a suitable solvent. In polar solvents, such as water, the required repulsion between the nanoparticles is obtained by a sufficiently high surface charge. However, this high surface charge is often realized by using strongly acidic or alkaline dispersions of the oxide nanoparticles. Such corrosive environments can lead to the oxidation and dissolution of common co-catalyst materials such as copper. To overcome this limitation, this work demonstrates the binding of ligands to the nanoparticles surface that retain their charge under milder conditions.

Both sodium ascorbate and sodium citrate were used as ligands to functionalize TiO2 nanoparticles to produce stable colloidal dispersions at neutral pH. Zeta potential measurements indicated that a strong negative surface charge is induced, which keeps the particles from agglomerating. The presence of the surface ligands could be confirmed by FT-IR and highly translucent gels were produced.

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18 Byloff Johanna

Al2O3 Interlayer Influence on Mechanical and Interfacial Properties of Al Thin Films on Polyimide

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Metal thin films on polymers serve a variety of applications in industry, medicine and space travel. The Al-Polyimide (PI) system investigated in this study offers high temperature resistance and good adhesion properties between substrate and coating. Previous studies [1, 2] attributed favorable adhesive properties to the natural formation of a thin amorphous Al-O-C interlayer [3] (IL, 5 nm thick) between metal film and PI substrate. Through a combined atomic layer (ALD) and physical vapor deposition (PVD) setup, we are uniquely able to mimic interlayers artificially over a wide thickness range to study their mechanical and interfacial benefits. Using this setup, Al films (150 nm) with different Al2O3 interlayer thicknesses (0, 0.12, 1, 5, and 25 nm) were deposited on a polyimide substrate. These bi-layer samples were subjected to equi-biaxial tensile loading [4] and unloading with in-situ X-ray diffraction and electrical resistivity measurements at Synchrotron SOLEIL. The evolution of Al film stress, width of the Al diffraction peak and electrical resistivity as a function of the applied strain and IL thickness could be determined. The Al layer thickness and microstructure as well as the artificial interlayers were investigated using TEM analysis. Additionally, post-mortem SEM images were analyzed to obtain crack density and spacing, and correlate well to observed differences in the shape of the stress-strain curves. Significant embrittlement was observed only in the 25 nm interlayer sample. Comparing 5 nm artificial and natural interlayer shows a similar resistivity but a difference in yield strength. Ongoing work includes studying the interlayer chemistry and high-resolution cross-sectional FIB/TEM analysis.

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19 Del Campo Alexia

Microfluidic Fabrication of Oscillation Shielding Coatings in Microbubbles for Selective Acoustic Interactions

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CONFIDENTIAL

20 **Bernhard Tim**

Comparing Performant Molecular Methods to Simulate Polymer Networks with Entanglements

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Molecular simulations of polymer networks allow for otherwise impossible insights into the relationship between the microscopic structure and the macroscopic properties of materials. Current simulation studies are limited to relatively small systems and/or short time frames, making accurate predictions of macroscopic properties difficult. This is especially true for highly fluctuating systems such as near-critical polymer networks (networks that just passed the solution-gel transition). Understanding the influence of the microscopic structure on the macroscopic properties would be of special interest for those near-critical networks, as these networks could serve important applications for example in medicine and health technology. Common remedies to simulate such systems include the use of soft potentials to speed up the dynamics, which usually has the side effect of not realistically modelling entanglements anymore. However, entanglements are a crucial aspect of polymer physics, giving rise to many of the properties generally associated with polymers, such as creep rate, modulus, and viscoelasticity. That's why there is great interest in attempts to re-introduce the effect of entanglements in coarse-grained simulations with soft potentials. Here we present an overview of a selection of simulation procedures to determine various properties of polymers in a performant way while taking entanglements into account. The comparison includes classical Kremer-Grest Molecular Dynamics simulations [1,2], Dissipative Particle Dynamics with slip-springs [3,4] and a novel Force-Balance procedure with slip-links.

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21 **Agrawal Prajwal**

Multi-Scale Volumetric Printing

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CONFIDENTIAL

22 Dreimol Christopher

Iron-Catalyzed Laser-Induced Graphitization: A Novel Approach to Produce Sustainable, Bio-Inspired Electrodes with Tunable Iron Phases

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Traditional electronic devices are made of non-renewable and often toxic materials, which can lead to serious environmental contamination upon their disposal. A promising strategy for producing sustainable electronics is the direct writing of laser-induced graphene (LIG) electrically conductive patterns on biological and bio-based substrates. However, high ablation rates, the need to use controlled atmosphere, toxic fire retardants and multiple lasing steps limit the applicability of conventional LIG processes to produce sustainable electronic devices.

We have introduced iron-catalyzed laser-induced graphitization (IC-LIG) as an innovative technique enabling to engrave large-scale electrically conductive patterns on thermally sensitive substrates such as wood and wood-derived materials [1]. Our approach makes use of an aqueous bio-based coating, inspired by the historical iron-gall ink, which protects the wood surface from laser ablation and thermal damage while preserving its mechanical properties. Thanks to our approach, it is possible to engrave highly conductive (up to 2500 S m-1) patterns even on thinnest wood veneers (> 400 µm) and cellulose paper within a single lasing step in ambient atmosphere using a conventional CO2 laser setup.

Here, we explore further the possibilities offered by our IC-LIG approach by elucidating the catalytic effect of iron under different lasing conditions. We can control the iron-carbon composite structure at the nano- and microscale level, e.g., by tuning the concentration of iron in the ink. This, in turn, allows us to tune the iron phases in the resulting IC-LIG materials. By precisely controlling the laser parameters and setup we are able to fabricate bio-inspired surface patterns at the meso- and macroscale, controlling the structure as well as the electrical properties on a multiscale level, allowing us to fabricate sustainable electrodes for prospective uses as energy storage and electrochemical devices.

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23 Scherrer Simon

Rolling or Sliding? Characterising Micro-Particle Motion and Friction

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The macroscopic behavior of many colloidal systems, including the rheology of dense suspension, typically arises from small-scale friction forces between particles. Lateral force microscopy (LFM) provides access to sliding friction measurements at the nanoscale by determining the lateral forces between a fixed particle, and a countersurface. However, in addition to pure sliding, particles in a fluid are also free to rotate. Thus, characterization of rolling friction forces associated with single, unrestricted particles remains practically unexplored. We have developed LFM colloidal probes that not only allow free rotation of an encapsulated particle but also simultaneous imaging of the contact via fluorescence microscopy. We analyze the three-dimensional rotation of particles by tracking fluorescent markers on the colloid. At the same time, we obtain the lateral forces acting on it, resolving local information about the correlation between contact forces and motion. The probe can be adapted to measure either sliding or rolling friction coefficients. It is for the first time possible to study how surface properties such as roughness and adhesion affect the friction and motion of free microparticles in a liquid medium, and in turn the macroscopic behavior of dense suspensions, which are of paramount importance in colloid and material science.

Figure 1: False colored SEM scans of the experimental setup of the colloidal probe (blue) with rough particle (red).

24 Boolakee Oliver

Lattice Boltzmann for Linear Elastic Solids

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Recent modeling frameworks to predict the mechanics of additive manufacturing processes involve both fluid and solid mechanics, with the former often solved using the lattice Boltzmann method. Motivated by the wish to model all physics with the same method, we propose a novel lattice Boltzmann formulation to solve the equations of linear elastic solids in the quasi-static limit [1]. In comparison to previous attempts in the same direction [2, 3], our approach aims at higher accuracy and efficiency as well as retaining all computational benefits of the lattice Boltzmann method. Additionally, novel boundary formulations for the physical boundary conditions of Dirichlet and Neumann-type are introduced that enable the simulation on domains with arbitrary curved boundaries in 2D [4]. For both the method in the bulk and the boundary formulations, the asymptotic expansion technique [5, 6], is employed for a systematic derivation of the required expressions.

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25 Boev Dimitar

Microscope-Assisted Acoustic DLP (Bio-)printing

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CONFIDENTIAL

26 Klipp Alexander

Enhanced Transfection by Release of an Endosomal Escape Mediating Protein

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Introduction: Gene delivery faces many hurdles on the way to efficient transfection. One obstacle of non-viral vectors is the escape from the endosomal compartment [1]. Our aim is to enhance the transfection of a system based on the human mitochondrial transcription factor A (TFAM) by boosting its endosomal escape [2]. This system (TFAMoplex) is composed of two distinct fusion proteins. One protein consists of TFAM fused to a phospholipase C (PLC), which enables endosomal escape while the second protein is composed of TFAM fused to the vaccinia-related kinase 1 (VRK1), which is thought to enhance nuclear uptake. To increase the endosomal escape, we aimed to release the PLC from the TFAMoplex in a controlled manner, such that it can better cleave the endosomal membrane.

Methods: A linker harboring cleavage sites recognized by endosomal proteases cathepsin L and furin was inserted between PLC and TFAM. Cleavage of the cathepsin-furin (CF) linker was assessed by SDS-PAGE analysis. Transfection efficiency of this linker system was evaluated by delivering a plasmid encoding for green fluorescent protein (GFP) and quantifying GFP fluorescence in cell culture.

Results: Linker cleavage was confirmed by SDS-PAGE. Transfection with the CF linker system resulted in 3.5 x increased efficiency compared to the system without the CF linker as well as to the system harboring the non-cleavable linker.

Conclusion: Transfection efficiency of our TFAMOplex gene delivery system was increased by introducing a linker sensitive to endosomal proteases. Further studies are required to confirm that the CF linker is responsible for enhanced endosomal escape.

Acknowledgement: This work has received funding from the European Research Council (ERC) und the European Union's Horizon 2020 research and innovation program (grant agreement No 884505).

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27 Pereira Martendal Caroline

Unraveling and Refining Co-Processability of Metallic Feedstock in Multi-Material Laser Powder Bed Fusion

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Multi-material processes are gaining attention as a potential next evolutionary step in the additive manufacturing (AM) industry [1], due to their wider design space, elimination of additional joining and assembly operations, and ability to save expensive feedstock through selective deposition. Among the AM technologies, laser powder bed fusion (LPBF) is particularly notable for its fine features [1] and capability to print a wide range of metals and metallic alloys [2] with near full density. Consequently, LPBF has the potential to be an effective technique for developing multi-material printing technology, especially given the existence of commercial solutions for selectively depositing multiple metallic feedstocks in the powder bed. However, the development of Multi-Material LPBF (MMLPBF) requires extensive research to understand its limitations in terms of co-processability of the involved metals. The melting nature of the process makes the materials prone to intermix at the interface, which can promote good adhesion but limits the spatial resolution of multi-material designs and may also lead to phenomena such as the formation of brittle intermetallic compounds or liquid metal embrittlement, resulting in cracking. Therefore, laser exposure strategies that control penetration into neighboring materials are crucial for achieving structures with desired properties. This work presents material combinations with good co-processability though MMLPBF, along with strategies to enhance interface quality when co-processability is limited.

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28 Niggel Vincent

Imaging the Motion of Colloids in Dense Suspensions Under Shear

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Dense colloidal suspensions display different non-linear rheological responses. At high stresses this may include shear thickening, which is a general phenomenon whereby the viscosity of dense suspensions increases. This response can both cause problems in industrial processes, like during the mixing of dense pastes [1], but can also lead to the development of interesting materials for shock-absorption applications [2]. To influence this behavior, different factors can be tailored, such as the modification of the roughness of the particles, volume fraction, particle size and even the surface chemistry of the particles. However, a detailed microscopic insight on the origin of shear thickening is lacking. For a long time, it was believed that the increase in viscosity was the sole result of the formation of particle clusters held together by hydrodynamic forces. More recently, evidence has been gained to support the presence of force networks where particles come into contact under shear [3], which in particular in the discontinuous shear thickening regime come into play. Recently, the observation of the force chain network was reported [4], but a live visualization of those microscopic contacts, and of their effect on the overall flow, still remains elusive. We propose an alternative approach and employ a high-speed confocal instrument, coupled to a counter-rotating cone-plate rheometer allowing us to focus on the stagnation plane in the sample. We are thus able to image the relative motion between particles even at high shear rates.

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29 Góra Michał

Surface Force on Nano-Porous Materials

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Due to their distinctive properties, nano-porous materials have become increasingly popular in materials science and related fields [1-3]. The interaction of these materials with the surrounding environment is influenced by heterogeneous surface forces that occur on the material's surface. The presence of small openings in the porous material increases the amount of internal surface area, resulting in surface force kinetics, which is characteristic for such surfaces. Conducting a systematic study of surface forces on nano-porous surfaces is a novel approach that offers the opportunity to discover new (non-equilibrium) phenomena.

In this study, we employed the atomic force microscope and the extended Surface Force Apparatus (eSFA) to observe changes of free energy at different time and length scales. One of the nano-porous models was created using plasma-enhanced chemical vapor deposition, resulting in highly cross-linked plasma polymer films (PPFs) with pore dimensions below 10 nm in diameter [4]. Preliminary eSFA experiments on these films in air indicate a non-uniform distribution of charges on the PPF surface. In water, eSFA surface force measurements indicate a time-dependent evolution of the free Gibbs energy of the fluid. This phenomenon is believed to be related to the dipolar orientation of water molecules on the nanometer-scale porous films. Additionally, model surfaces with larger pores were produced using a focused ion beam technique on muscovite mica, yielding porous films with adjustable pore dimensions ranging from a few hundred nanometers in diameter. Examining surface forces on these nano-porous models of various sizes can offer insights into novel effects that occur in confined fluids.

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30 Balciunaite Aiste

Taking Topographical Cues from 2D to 3D: Contractile Skeletal Muscle Constructs Engineered with 3D Topography in Photopolymerizable Bioink

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Engineered, lab-grown contractile muscle tissue is of particular interest not only for its biomedical applications, but in revolutionizing robotics by allowing the use of a sustainable and biocompatible actuator, real muscle, to power a biohybrid robot. Unfortunately, we are thwarted in this goal by our inability to repeatedly and reliably engineer centimeter-scale, contractile muscle. In this work, we present an approach towards a standardized platform for functional skeletal tissue engineering. We demonstrate photopolymerization-based fabrication of contractile skeletal muscle tissue constructs, by developing a refractive index-matched bioink based on gelatin methacryloyl containing Matrigel and collagen. Mechanical stimulation or topographical cues are necessary to differentiate skeletal muscle tissue into contractile constructs by guiding cell alignment and recapitulating the *in vivo* cellular environment. Therefore, we introduce 2D topographical cues by using a thin film approach and seeding the cell-laden bioink onto microgrooved hydrogels, printed using xolography, a novel linear volumetric printing approach [1]. We introduce 3D topographical cues by using a coherent laser light biofabrication process (Filamented Light Biofabrication [2]) that produces parallel microbeams throughout the construct during the printing process. We show that 3D topographical cues are sufficient to result in contractile skeletal muscle constructs, and mechanical stimulation is not necessary. We also show that 3D topographical cues result in better alignment than 2D topographical cues. Finally, we demonstrate the ability to combine mechanical stimulation and force characterization of laser printed skeletal muscle constructs, by overprinting our bioink formulation onto a cantilever structure. In all, our results inform a standardized production of contractile skeletal muscle constructs necessary for biomedical applications of disease phenotype testing and drug screening, and of biohybrid designs of skeletal muscle actuators.

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31 Kavas Baris

Interlayer Temperature Stabilization via Closed-Loop Feedback Control in Laser Powder Bed Fusion

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CONFIDENTIAL

32 Albert Cristhiana

Corrosion Kinetics of Steel in Carbonated Pore Solutions

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Steel corrosion is a major cause of the early degradation of reinforced concrete structures. In particular, carbonation induced-corrosion might be more prominent when environmentally friendly cements are applied since these materials carbonate faster. In sound-reinforced concrete, the steel is protected by a passive film due to the high pH ~13 media, but this protective layer might no longer be thermodynamically stable in the pH 8-9 of carbonated concrete. The conventional approach to ensure the durability of these structures is to delay concrete carbonation. This is achieved by using concrete with lower porosity and increasing the cover depths of the reinforcement. A downside of this strategy is the higher material consumption and, again, the increase in the concrete CO_2 footprint. However, concrete carbonation is not always the issue, but rather the corrosion rate of steel. It becomes imperative to determine the actual corrosion kinetics of steel in carbonated media instead of just avoiding carbonation. In this project, we explore how the corrosion rates of steel are affected by three main factors: pore solution, microstructure, and moisture content of concrete. Initial findings reveal the significant influence of the ionic species in solution on the corrosion rates of steel. When immersed in a solution buffered at pH 8, the steel can even achieve a passive state if only bicarbonate ions are present. Thus, the low pH alone is not the primary reason for the instability of the passive film of steel in carbonated concrete. Conversely, the addition of chloride or sulfate species to the solution leads to corrosion rates up to two orders of magnitude higher than when these species are absent.

33 Deng Zhikang

Effect of Temperature on Glass to Iron-based Shape Memory Alloy Adhesive Shear Joints

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Glass beams are becoming increasingly prevalent as structural elements. Previous research has demonstrated that post-tensioning beams with Iron-based shape memory alloys (Fe-SMAs) can enhance their initial and post-fracture load-bearing capacity when adhesively bonded to the edges of laminated glass beams. In light of potential applications of laminated glass beams to support transparent roofs or facades and the range of temperatures to which the beams may be exposed, this study examines the bond behaviour of glass-to-Fe-SMA lap-shear joints with a selected epoxy adhesive at various temperature levels. The load-carrying capacity, failure mode, and slip behaviour are evaluated. The experimental results provide insight into the performance and limitations of the selected adhesive at different temperatures, thereby contributing significantly to the future implementation of adhesively bonded Fe-SMA tendons for post-tensioning glass elements.

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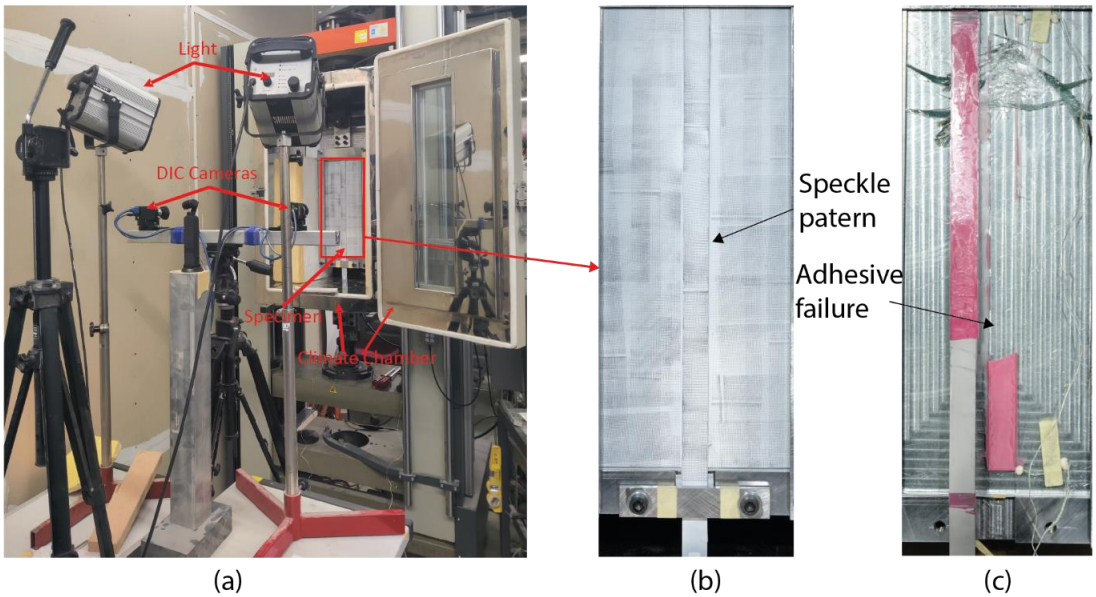

Figure 1 Test setup configuration (a), test specimen with DIC speckle pattern (b), and failure mode (c)

34 Ruckert Dominic

Detection and Excitation of Single Atomic Spins in a Scanning Tunneling Microscope

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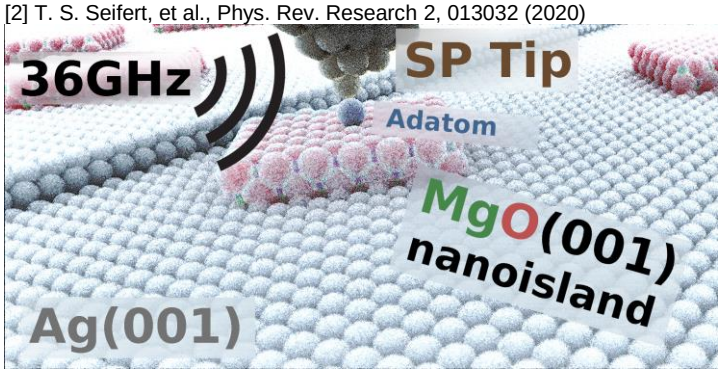
Properties such as the charge and spin states of single atoms are of high relevance in fields like catalysis, nanomagnetism, and quantum technologies. However, measuring the properties of single atomic objects is challenging, requiring high spatial resolution. The combination of electron paramagnetic resonance (EPR) and scanning tunneling microscopy (STM) allows probing and manipulation of single atoms and molecules adsorbed on ultra-thin insulating films [1]. This unique technique reveals the electronic structure of single and coupled quantum dots with <μeV energy resolution [2].

Here, we will demonstrate the technical implementation and basic principles of the EPR-STM technique. Further, we present the capabilities of the technique to resolve the charge states of atoms, magnetic interactions within an individual atom, as well as the interaction between multiple paramagnetic atoms. The studies of interactions between individual atoms are enabled by the capability of the STM to position individual atoms to predefined binding sites on the surface [1].

We are exploring new combinations of substrate, insulating film, and surface adsorbates with the aim of extending the relaxation times of a spin state and understanding relaxation mechanisms.

[1] Chen, Y., Bae, Y., Heinrich, A. J., *Adv. Mate*r. (2022)
[2] T. S. Seifert, et al., Phys. Rev. Research 2, 013032 (2020)



A spin-polarized (SP) scanning tip is positioned above the atomic adsorbate. A radio-frequency (RF) source induces a GHz alternating current at the tunneling junction between the tip's apex and the underlying adsorbate/substrate. The resulting fast oscillations of the adatom by piezoelectric coupling give rise to a resonance since the atom moves in the magnetic field gradient of the SP tip [2].

35 Verbeek Xanthe

Hidden Order in Cr_2O_3 and α-Fe_2O_3 as a Predictor for Exotic Magnetic Behavior

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Recently, magnetic multipoles have emerged as a powerful tool for predicting and understanding complex magnetic behavior such as magnetoelectricity and altermagnetism [1, 2]. Magnetoelectric materials show a coupling between electric and magnetic degrees of freedom, such that an applied electric field can induce a finite and proportional bulk magnetization and a magnetic field can induce a finite and proportional bulk polarization [3]. Altermagnetic materials are antiferromagnets that show non-relativistic spin-splitting along specific directions in momentum space [4]. We present first-principles calculations of a hidden order, in the form of these magnetic multipoles in Cr_2O_3 and its iron-based analog, α-Fe_2O_3, which are both easy-axis antiferromagnets at low temperatures. Besides the expected magnetic dipoles, we find many non-zero higher-order multipoles, including quadrupoles, octupoles, hexadecapoles, and triakontadipoles. We use symmetry considerations to relate these multipoles and their ordering to a linear, quadratic, and cubic (*anti-)* magnetoelectric effects, where in an anti-magnetoelectric effect the induced moments are ordered antiferromagnetically in the unit cell [5]. We confirm these predictions with ab-initio calculations of local magnetic moments induced by an electric field. Additionally, we perform band structure calculations to confirm the altermagnetic nature of α-Fe_2O_3 and relate this behavior to the ferroic ordering of higher-order magnetic multipoles.

[1] N. A. Spaldin et al. Phys. Rev. B 88, 094429 (2013)
[2] S. Bhowal, et al. arXiv:2212.03756
[3] M. Fiebig, J. Phys. D: Appl. Phys. 38, R1 (2005).
[4] L. Šmejkal, et al., Phys. Rev. X 12, 040501 (2022)
[5] X. H. Verbeek, et al., arXiv:2303.00513

36 Kercher Niklas

Van der Waals Materials for Spintronics

Niklas Kercher [1], Emir Karadza [1], Paul Noël [1], William Legrand [1], and Pietro Gambardella [1]

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Van der Waals materials have strong in-plane covalent bonding and weak interlayer interactions. The key advantage of these layered systems is the possibility to stack materials of various physical properties and atomically sharp interfaces, without elemental diffusion, enabling precise thickness control and high crystal quality [1].

Following the recent discovery of ferromagnetism and antiferromagnetism in single-layer compounds, van der Waals-based spintronics has emerged as a promising avenue for research. For example, exfoliated low-symmetry transition metal dichalcogenides are expected to achieve more efficient current-induced switching of a 2D magnet via unconventional spin-orbit torques [2]. Compared to layers grown by physical deposition methods, the ability to stack materials of different crystallographic symmetries is a significant advantage to seize and explore magnetic phenomena. In this poster, I will present our first results on the fabrication of magnetic van der Waals heterostructures and their characterization using the anomalous Hall effect and the magnetooptical Kerr effect.

[1] K. S. Novoselov et al., Science 353, aac9439(2016).
[2] Y. Liu and Q. Shao, ACS Nano, 14, 8, 9389–9407 (2020)

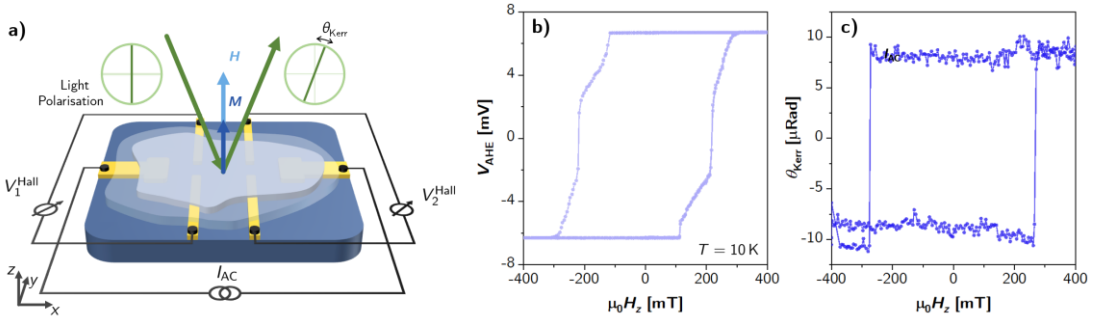

Fig. 1: Simultaneous electrical and optical characterization of an encapsulated Fe3GeTe2 as a function of external magnetic field parallel to the easy axis of the magnetisation: a) Schematic illustration of the sample, electrical contacts, and optical detection. b) Electrical measurement of the anomalous Hall voltage, and c) optical measurement of the Kerr rotation at 10 K.

37 Glauser Yannick

Inverse Design of Optical Fourier Surfaces

Yannik M. Glauser [1], Patrick Benito Eberhard [1], Hannah Niese [1], Juri G. Crimmann [1], Valentina G. De Rosa [1], Nolan Lassaline [1,2], Daniel Petter [1], and David J. Norris [1]

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[2] Nanomaterial and Devices, DTU Physics, Technical University of Denmark

The ability to precisely control the propagation of light in various media is crucial for modern technology. Optical nanostructures which strongly interact with light are integrated in a wide range of devices, such as solar cells, biosensors, and optical data transmitters. However, current lithographic methods typically impose limitations on the design of practically feasible surface structures. Most patterns are restricted to square-shaped profiles with only two depth levels (binary), which limits their optical performance. Here, we investigate the implementation of thermal scanning-probe lithography to fabricate “wavy” grayscale surface profiles, known as Fourier surfaces. They can be precisely designed based on continuous functions and fabricated in a variety of optical materials and metals, providing significantly increased control over their spatial Fourier spectrum compared to binary profiles [1,2]. We use these optical Fourier surfaces as reflective phase-only holograms in silver (Ag) to control the amplitude of the diffracted wavefront in the far field (Fourier domain). Due to the non-linear relation between their surface profile and diffraction output [3,4], an iterative Fourier transform algorithm based on the Gerchberg-Saxton algorithm [5] was developed to design the optical Fourier surface holograms. As one of many applications in microscopy, this could enable the creation of arbitrarily shaped light beams by compact and efficient nanodevices.

[1] N. Lassaline, et al., Nature 582, 506 (2020).
[2] N. Lassaline, et al., Nano Lett. 21, 8175 (2021).
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[4] J. E. Harvey & R. N. Pfisterer, Opt. Eng. 59, 017103 (2020).
[5] R. W. Gerchberg & W. O. Saxton, Optik 35, 237 (1972).

38 Dezauzier Raphael

A Microfluidic Platform for the Formation of Spheroids for Personalized Cancer Treatment

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CONFIDENTIAL

39 van Schie Laura

Imaging Domain Walls in RE-TM Ferrimagnetic Alloys via NV Magnetometry

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Magnetic racetrack devices are micron to nanometre lines patterned in nanometre stacks of magnetic and nonmagnetic materials. Recently, a class of materials known as ferrimagnets have gained importance as they have a partially compensated magnetic moment. Depending on their composition and temperature, the degree of compensation can be tuned to mimic more closely that of a ferromagnetic or an antiferromagnetic material and the dynamics of the system can be changed[1]. Understanding the dynamics of magnetic structures and, in particular, domain walls in such devices is a key aspect of spintronics research, as devices based off these geometries will be used for the next generation of magnetic memory and logic. The motion of domain walls induced by applied field or current can be tuned by changing material properties, and intrinsic characteristics of the system that govern said response i.e. by changing the width, chirality, strength of the magnetisation. Utilising quantum sensing techniques can help us to directly image the changes in domain wall properties in a noninvasive way. Nitrogen Vacancy Magnetometry (NVM) probes the electron transitions of a nitrogen defect in a diamond lattice. In this system, the transitions are highly sensitive to magnetic fields, making it suitable to study a wide range of phenomena[2]. In a scanning configuration, resolutions near 50 nm can be achieved. Images of the stray fields generated by different magnetic textures can be used to derive key domain wall properties, giving us a way to determine the properties of the ferrimagnetic materials at different compensations. This study would provide an invaluable tool in determining what mechanisms are responsible for the change in dynamics in these systems.

[1] G. Sala, et. al., Adv. Mater. Interfaces 2022, 9, 2201622
[2] Schirhagl R, et. al., Annu Rev Phys Chem. 2014, 65:83-105

40 Wohlwend Jelena

Generating a full gamut of structural colors based on self-organized dielectric nanocup metasurfaces

Jelena Wohlwend [1], Claudiadle Polani [1], Anna Hilti [1], Ralph Spolenak [1] and Henning Galinski [1]

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CONFIDENTIAL

41 Monti Chiara

A New Al-Cu Alloy for Laser Powder Bed Fusion (LPBF) developed via Ultrasonic Atomization

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[2] Materials, Processes and Sustainability Group, inspire AG

CONFIDENTIAL

42 **Achatz Julia**

Revolutionizing Roundwood Sorting: A Novel CNN-based Recommendation System for Improved Quality and Species Sorting with Image and Numerical Data

Achatz Julia [1], Lukovic Mirko [2], Hilt Simon [3], Lädrach Thomas [4], Schubert Mark [5]

[1] WoodTec Group, Cellulose & Wood Materials, Empa
[2] WoodTec Group, Cellulose & Wood Materials, Empa
[3] Maastricht University/Empa
[4] OLWO AG
[5] WoodTec Group, Laboratory for Cellulose & Wood Materials, Empa

Roundwood sorting is still a manual process in many Swiss sawmills, requiring employees to visually inspect and categorize thousands of logs per day. The heavy workload can be both physically and mentally taxing, and can lead to increased rates of human error. The accuracy reached by manual judgment is typically lower than 85% [1]. State-of-the-art automation systems like X-ray log scanners are expensive and difficult to integrate into existing process lines. This project proposes a novel recommendation system that leverages recent advances in image classification to automate roundwood classification by quality and species. The system integrates a camera to capture cross-sectional images of logs and record numerical data, such as length, deviation, and diameter. The analysis of the dataset highlights the challenges of data imbalance and noise, which makes classification difficult and, in some cases, impossible. However, by using a selected dataset with reduced noise, state-of- the-art CNNs can extract quality features. Furthermore, this work shows a detailed analysis of the noise and possible improvements for the future. The species determination reaches over 90% accuracy on the entire dataset for main species spruce and fir. The accuracy on the selected dataset for three quality classes is 72%. Overall, this research highlights the potential of Machine Learning in enhancing roundwood sorting processes and presents a novel system that can improve the efficiency and accuracy of the process.

[1] P. Niemz, et. al., Springer Handbook of Wood Science and Technology, (2023).

Figure & Caption:

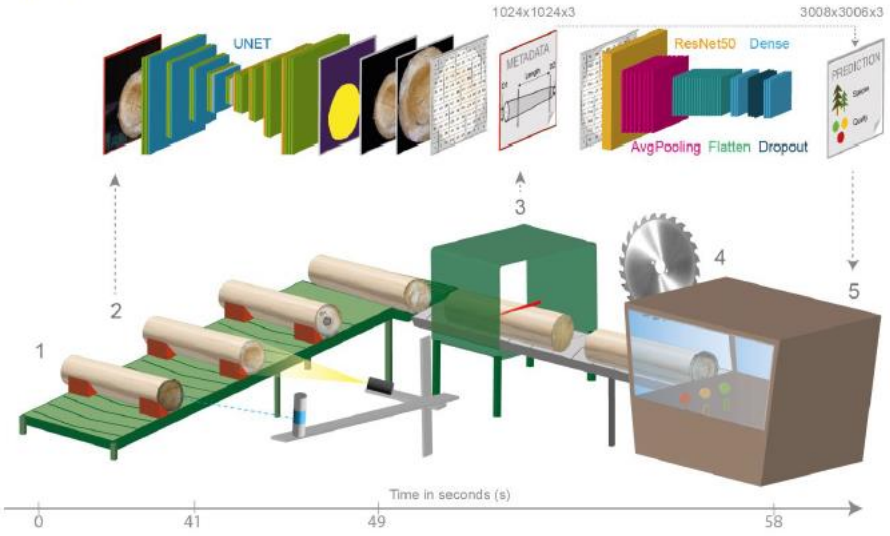

Figure 1: This schematic representation illustrates the roundwood sorting process and the Machine Learning recommendation system. 1: Calculation of the travel distance for the camera unit and track displacement for synchronization, 2: Trigger signal for the camera is generated and picture is taken, 3: Scanner to determine length, diameter and deviation, 4: Cut the tree to the right length and/or for quality reasons, 5. Quality decision by the operator. The upper half of the image shows the Machine Learning process running synchronously. First the image is preprocessed mainly including segmentation, cropping and normalizing. A prediction is made with e.g. a ResNet50 model followed by some Pooling, Dense and Dropout layers. An average duration of the sorting process at each step is shown below.

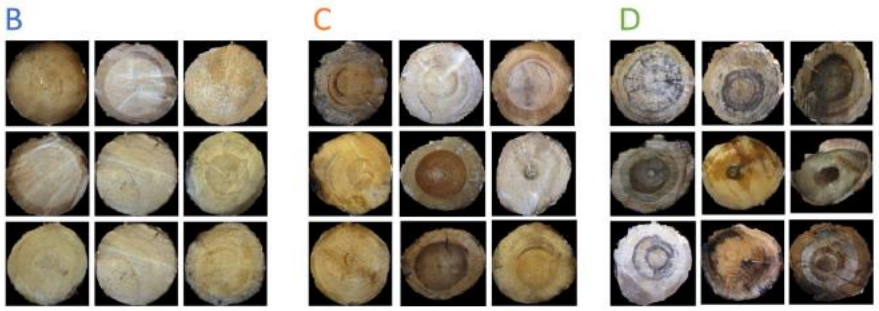

Figure 2: Examples of training images in each class after segmentation and cropping.

43 Choi Young

Stretch Limits and Damage of Endothelial Monolayers

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CONFIDENTIAL

44 Tao Siyuan

An Injectable Living Hydrogel With Encapsulated Probiotics To Fight Against Pathogen Infections In Wounds

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Biointerfaces, Materials meet life, Empa

CONFIDENTIAL

45 Antonopoulou Maria-Nefeli

Concurrent Control Over Sequence and Dispersity in Multiblock Copolymers

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Controlling monomer sequence in synthetic macromolecules is a major challenge in polymer science and the order of building blocks has already been demonstrated to determine macromolecular folding, self-assembly and fundamental polymer properties. Dispersity is another key parameter in material design, with both low and high dispersity polymers displaying unique properties and functions.[1] However, synthetic approaches that can simultaneously control both sequence and dispersity remain experimentally unattainable. In this talk we will present a simple, one pot, and rapid synthesis of sequence-controlled multiblocks with on demand control over dispersity while maintaining high livingness, good agreement between theoretical and experimental molecular weights and quantitative yields. Key to our approach is the regulation in chain transfer agent activity during controlled radical polymerization that enables the preparation of multiblocks with gradually ascending ($Đ$=1.16 →1.60), descending ($Đ$=1.66 →1.22), alternating low and high dispersity values ($Đ$=1.17 →1.61 →1.24 →1.70 →1.26) or any combination thereof.[2] The enormous potential of our methodology was further demonstrated through the impressive synthesis of highly ordered pentablock, octablock and decablock copolymers yielding the first generation of multiblocks with concurrent control over both sequence and dispersity.

[1] Whitfield, R., Parkatzidis, K., Truong, N. P., Junkers, T. & Anastasaki, A. Tailoring Polymer Dispersity by RAFT Polymerization: A Versatile Approach. *Chem* **6**, 1340-1352 (2020).
[2] Antonopoulou, MN., Whitfield, R., Truong, N.P., Wyers D., Harrisson S., Junkers T., Anastasaki A. Concurrent control over sequence and dispersity in multiblock copolymers. *Nat. Chem.* (2021).

46 Greitens Christina

BRET-Assay for Tracking Transfected Plasmid DNA in Cells

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Efficient non-viral gene delivery is a key bottleneck in gene therapy. Yet, little is known about the intracellular fate of the delivered genes since the transfected DNA can currently not be visualized in sufficient resolution. This lack of understanding contributes to the moderate transfection efficiencies of current non-viral delivery systems.

One state-of-the-art fluorescence microscopy-based plasmid tracking approach uses the *lacO/LacI*-GFP system [1]. Recombinantly expressed *LacI*-GFP binds to the lactose operator (*lacO*) which is present in multiple copies on the transfected DNA plasmids, allowing their localization. However, such approaches suffer from photobleaching, artefacts, and high background signal from unbound *LacI*-GFP.

We propose to improve the *LacI*-based DNA visualization method using bioluminescence resonance energy transfer (BRET) [2] . For the detection of BRET signal, the donor (nanoluciferase) should bind in close proximity to the acceptor protein (mCyRFP) on the transfected plasmid. Therefore, the donor and acceptor proteins were fused to bacterial transcription factors. These detect and bind a specific operator cassette directly adjacent on the transfected plasmid, resulting in a specific BRET signal [3].

Individually, the fusion constructs were found to localize to DNA-dense regions. BRET background signal was negligibly low whereas BRET signal was strong with a donor-acceptor fusion protein. Next to the testing of the operator cassette plasmid, this sensitive imaging system is further evolved for the tracking of intracellular plasmid DNA over time. With this BRET method, the efficiency of any non-viral transfection agent may be assessed and, eventually, improved. This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (grant agreement No 884505).

[1] C.C. Robinett, et.al., Cell Biol. 135, 1685-1700 (1996)
[2] S. Angers, Proc. Natl. Acad. Sci. U. S. A. 97, 3684-3689 (2000)
[3] J.L. Ramos, Microbiol. Mol. Biol. Rev. 69, 326-356 (2005)

47 Hofmann Marco

Pulse Shaping Strategies for Efficient Spin-Orbit Torque Switching of Magnetic Tunnel Junctions

Marco Hoffmann [1], Viola Krizakova [1], Vaishnavi Kateel [2], Kaiming Cai [2], Sebastien Couet [2], and Pietro Gambardella [1]

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[2] imec, Kapledreef 75, 3001 Leuven, Belgium

Employing electric currents for the switching of magnetic tunnel junctions (MTJs) [1] opens new opportunities to improve magnetic memory devices. The writing energy for reversing the magnetization of the free layer in the MTJ is a key figure of merit for comparison with competing technologies. Most investigations of magnetization switching induced by so-called spin-orbit torques (SOTs) rely on square current pulses. However, given that the magnetization reversal induced by this reversal mechanism consists of a two-phase process involving domain nucleation and subsequent domain wall propagation, different pulse shapes improve the switching efficiency. Here, we investigate SOT-induced switching as a function of pulse shape, amplitude, and duration. We show that non square pulses achieve a substantial reduction of writing energy without compromising the switching probability and speed. Depending on the pulse width, the current induced temperature evolution and the domain wall propagation time, large voltage amplitudes are most effective at different parts of the pulse. Time-resolved measurements of the switching process reveal how the nucleation times are also strongly impacted by the pulse shape and reflect the temperature dynamics. Micromagnetic simulations corroborate these results.

[1] A. Manchon, et. al., Rev. Mod. Phys. 91, 035004 (2019).

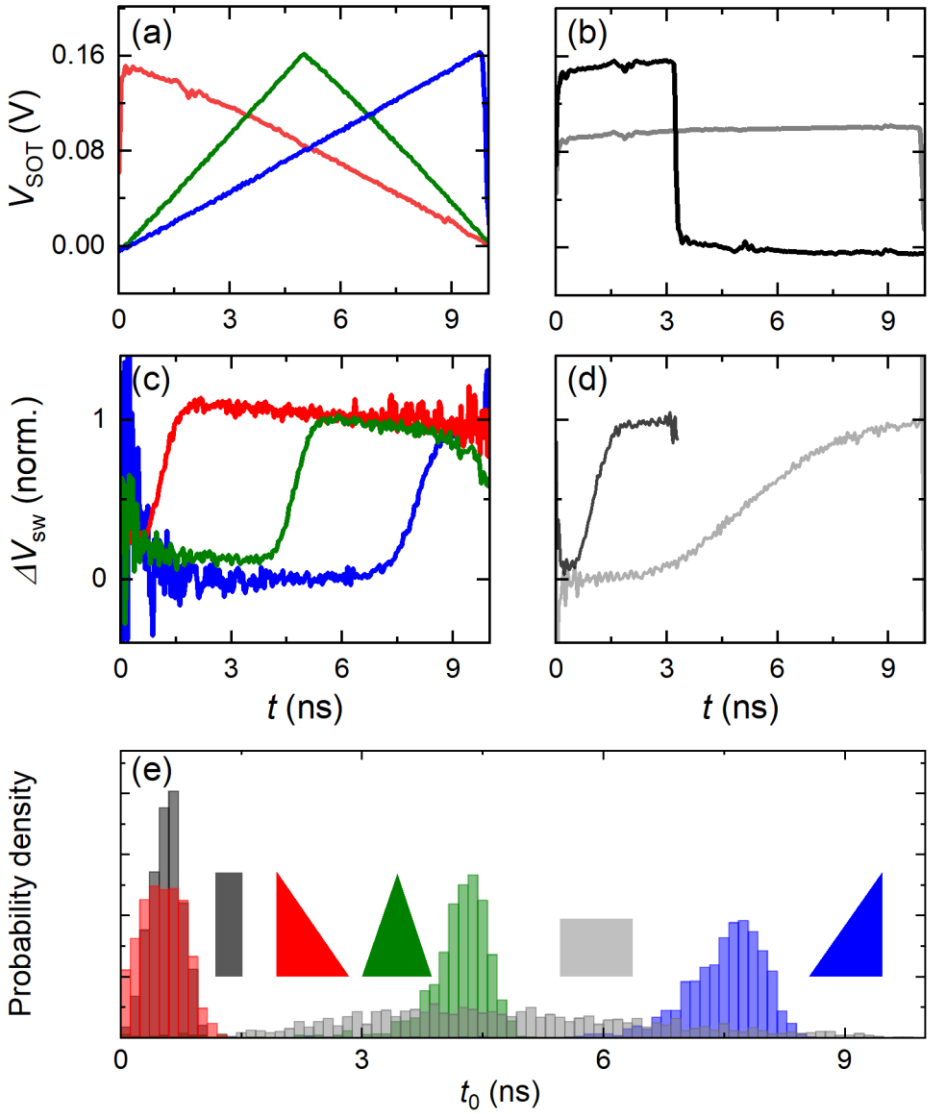

Figure 1: Applied (a) triangular and (b) square voltage pulse shapes with the respective average magnetization switching traces in (c) and (d), respectively. (e) Histograms of the individual reversal onset times obtained from single switching events for each of the five pulse shapes.

48 Zhang Zhiyuan

SonoTransformers: Acoustically Actuated Ultrafast Shape Morphing Micromachines

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CONFIDENTIAL

49 Bernhard Stéphane

Redox Responsive Nanogels for Intracellular Drug Delivery

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[2] Applied Physical Chemistry Lab, Dept. of Chemistry, Materials and Chemical Engineering, Politecnico di Milano

Nanogels are a class of nanoscale cross-linked polymer networks exhibiting high performances as nanocarriers for intacellular drug delivery.[1][2] These objects bridge the favorable properties of hydrogel biomaterials, including high water content, biocompatibility, and simple drug loading, with the advantages of the nanoscale, such as facilitated cellular uptake and the delivery of therapeutic to the cytosol. However, direct loading of the therapeutics in the nanogel can result in diffusion mediated release before internalization of the carrier. Stimuli-responsive release of the therapeutics within the cell would reduce off target side effects. Disulfide containing chemistries can act as responsive linkers for specific intra cellular cleavage in the presence of glutathione (GSH),[3] which has a higher concentration in the cell. In this work, we synstetised a redox responsive nanogel drug delivery carrier using a self-immolating disulfide linker. Functional nanogels were synthetized through emulsion-evaporation of azide-functionalized poly(ethylene glycol) (PEG) and poly(ethyleneimine) (PEI). A fluorescent model drug was then modified with a disulfide linker and coupled to the nanogel through click chemistry. In the presence of GSH the disulfide bond reacts with itself, releasing the therapeutic without leaving traces of the original chemical modification. We are currently investigating the release efficiency various cleaving conditions and the release of capacity of the linker to release the model drug without chemical modification. Overall, this work aims to develop a redox responsive nanogel drug delivery carrier for intracellular release of therapeutics free of chemical modification.

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[2] E. Mauri et al. Eur. Polym. J., 94, 143–151. (2017)
[3] C. F. Riber et al. Adv. Healthc. Mater., 4, 12, 1887–1890. (2015)

50 Born Friederike

Microfluidic Platform to Visualize and Quantify Bacterial Response to Dynamic Drug Treatments

Friederike-L. Born [1], Petra Jusková [1], Annelies Zinkernagel [2] and Petra S. Dittrich [1]

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[2] Universitätsspital Zürich, Zürich

Heterogeneity within bacterial populations is considered an important factor in developing antibiotic resistance and persistence. Assays routinely used in clinics and many miniaturized platforms study bacterial death under steady-state dosing, which does not sufficiently address this intercellular heterogeneity. Moreover, mimicking in vivo conditions, where bacterial cells are temporarily exposed to different antibiotic concentrations, is only possible using dynamic models. We developed a microfluidic method to investigate the antibiotic treatment effects on bacterial cells over time. The bacterial cells were confined in a thin hydrogel layer in a central compartment, while side channels enabled the supply of drugs,medium and stains. Drug gradients were generated using syringe pumps and supplied to the cells for up to 18 hours. The immobilization of the cells in hydrogel during drug dosing allowed for time-lapse microscopy with-single cell resolution. We characterized the developed platform using quality control strains *E. coli* ATCC 25922 and *E. coli* ATCC 35218, which are exposed to a single drug (amoxicillin or clavulanic acid) and combinations of these drugs. First, we confirmed that the minimum inhibitory dose at constant amoxicillin supply for *E. coli* ATCC 25922 is in accordance to the value listed in the clinical reference guidelines. Next, we compared the constant supply of amoxicillin with intermittent supply, i.e. alternating supply of drug and drug-free medium. Preliminary results indicate that cells exhibit different growth behaviour depending on the drug dosing profile. Additionally, we investigated the dynamics of growth inhibition of amoxicillin-resistant *E. coli* ATCC 35218 under combined amoxicillin/clavulanic acid treatment, where we simulated a typical profile of drug administration in patients. Again, the observed cell growth behaviour deviated from results for constant drug supply. Our findings highlight the importance of precise dosing profiles for studies on drug effects.

51 Cipolato Oscar

Nanoparticle-Enhanced Laser Tissue Soldering

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[2] Particles Biology Interactions Laboratory, Department of Materials Meet Life, Empa

Sutures and staples are commonly used in surgery to bond tissues together. However, their invasiveness often causes infections, leaks and other complications that pose a significant threat to wound healing and the life of the patient. To avoid these complications, research has been conducted to look for replacements or suture support material. Surgical adhesives and glues seem an appealing choice, however, face their own challenges, including low adhesion and chemical stability, toxicity and foreign body reactions. Laser Tissue Soldering (LTS) is an emerging technology that can form strong watertight bonds and can be used as an alternative to sutures and staples. The solder paste can be made using a proteinaceous base. The laser light is used to increase the temperature of the paste in a precise and non-contact manner. Thermal denaturation and following crosslinking of the paste with the proteins in the tissue provide a strong watertight bond. While highly promising, thermal control in laser tissue soldering is of utmost importance. Infrared thermal imaging is only able to measure the surface temperature and not the temperature at the interface between solder and tissue. Moreover, it cannot be used for non-superficial wounds. Fluorescent nanothermometers that work in the biological optical windows overcome these problems. Mixed with plasmonic nanoparticles that can efficiently convert light into heat, the temperature during the soldering process can be measured and controlled. In this work, a novel material that is used as solder paste for laser tissue soldering is presented. Its application on ex vivo and in vivo models is studied and demonstrated. This work opens a new avenue to accurate and precise temperature control during laser tissue soldering, thus overcoming its major drawback.

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52 Töpfer Ueli

Controlling Self-Propulsion of Micro-Swimmers with Light

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Active microparticles are often used as model systems for biological micro-swimmers, e.g. bacteria [1]. However, unlike their biological counterparts, artificial swimmers cannot adapt their activity in response to local stimuli, i.e. they cannot autonomously adapt to different environments. Whereas in larger-scale soft-robotic devices adaptation can be encoded during fabrication [2], at the colloidal scale spatio-temporal adaption to external stimuli remains elusive. We developed micro-swimmers with an optically controllable activity by fabricating silica Janus particles (JPs) with a photoresponsive titania hemisphere. Our JPs self-propel in response to an external AC electric field due to electro-hydrodynamic flows, which are generated by the asymmetry in dielectric properties of the two hemispheres. Upon local illumination, the conductivity of the titania hemisphere increases, allowing for the adaptation of the propulsion velocity, as shown in the figure. With these two orthogonal regulation schemes, we achieve a high degree of control over the motion of individual particles in an ensemble, opening up new possibilities for the development of adaptive light-controlled micromotors.

[1] C. Bechinger, et. al., Rev. Mod. Phys. 4, 88 (2016) [2] J. Hu, et. al., Adv. Intell. Syst. 1, 1900050 (2019)

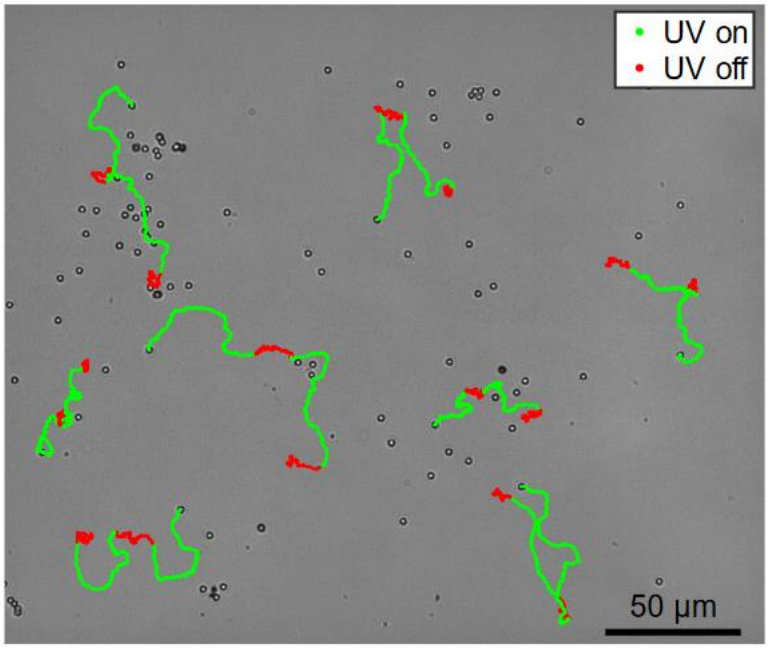

Figure: Selected tracks of photoactive JPs under cyclically switched illumination (30 s on/off) and constant electric field (83 kV/m).

53 Tošić Tara

Magnetic Frustration in Materials: the What, the Why, and the How of Simulation

Tara N. Tošić [1] and Nicola A. Spaldin [1]

[1] Materials Theory, D-MATL, ETH Zurich

We use a first-principles based approach to simulate the dynamics of magnetism in hexagonal Yttrium Manganite (h-$YMnO_3$). The magnetic frustration within these compounds is of particular interest: magnetic moments within the material experience a tug-of-war between competing interactions with their environment. Given that all the system's constraints cannot be simultaneously satisfied, it is not always straightforward to predict how frustrated systems will behave and what hidden physics lies within them. The understanding and manipulation of magnetic fields has been key to some of the most important technological breakthroughs in our society, from magnetic memory storage, to transformers and inductors, to nuclear magnetic imaging [1]. With the continuous improvement of state-of-the art computational techniques, new magnetic systems are constantly being discovered. We show that the magnetic frustration in this class of materials gives rise to exotic metastable states and magnetic domains and explain neutron scattering experimental results [2]. Additionally, we cast the magnetic order into a multipolar formalism, which helps us to visualize hidden order across magnetic domain walls, as well as domain walls within domain walls.

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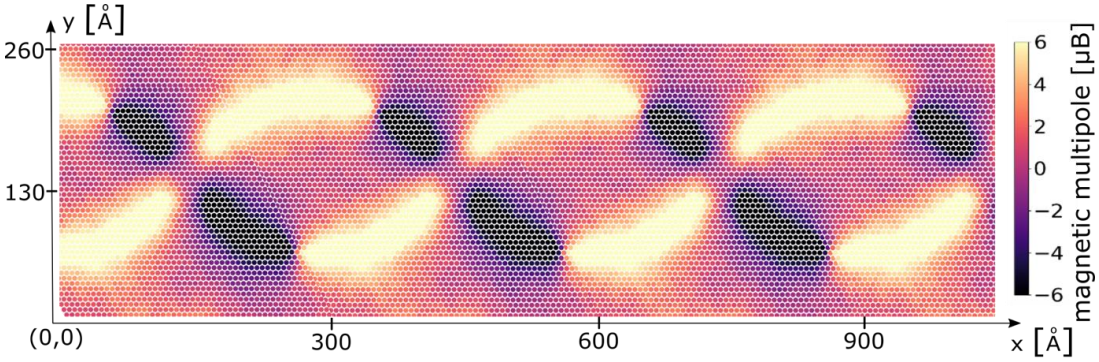

Figure: Spin Dynamics simulation of a repeating pattern of magnetic domain walls in hexagonal $YMnO_3$. Negative and positive values indicate the right and left-handed toroidal components of the magnetic multipoles, respectively.

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Nanodroplet Flight Control in Electrohydrodynamic Redox 3D Printing

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Electrohydrodynamic 3D printing is an additive manufacturing technique with enormous potential in plasmonics, microelectronics, and sensing applications, thanks to its broad materials palette, high voxel deposition rate, and compatibility with various substrates. In the printing process, charged droplets ejected from the nozzle experience a focusing scheme in response to the electric field concentration at the deposited structure, ensuring sub-micrometer resolution but, at the same time, leading to geometry-dependent landing positions, which complicates the fabrication of complex 3D shapes. The low level of concordance between design and printout seriously impedes the development of electrohydrodynamic printing and rationalizes the simplicity of the designs reported so far. In this work, we arbitrarily break the electric field centrosymmetry to study the resulting deviation in the flight trajectory of the droplets. Comparison of experimental outcomes with predictions of a finite element model provides new insights into the droplet characteristics and unveils how the product of droplet size and charge uniquely governs its kinematics. Ultimately, the new knowledge enables the development of an optimization tool to derive print paths counterbalancing the electric field distortion, thereby achieving a high degree of geometrical conformity.

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